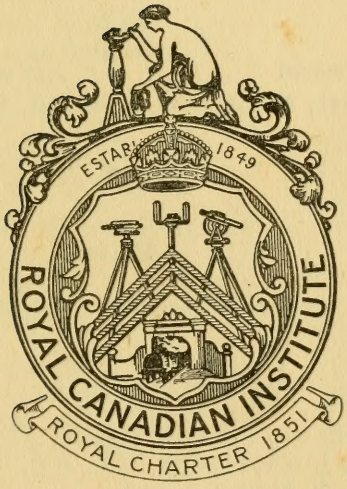
TRANSACTIONS

OF THE

Royal Canadian Institute

VOLUME XI.



UNIVERSITY OF TORONTO PRESS

L217

OFFICERS

OF

The Royal Canadian Institute

1917-18

President
J. MURRAY CLARK, M.A., LL.D., K.C.

1st Vice-President
J. C. FIELDS, Ph.D., F.R.S.

2nd Vice-President
G. H. LOCKE, B.Paed.

Secretary	J. PATTERSON, M.A.
Treasurer	W. B. TINDALL, Esq.
Editor	J. H. FAULL, B.A., Ph.D.
Librarian	D. R. KEYS, M.A.
Curator	H. JEWELL, Esq.

Members of Council

SIR FREDERIC STUPART.
J. J. MACKENZIE, B.A., M.D.
J. B. TYRRELL, M.A.
F. ARNOLDI, K.C.
J. C. McLENNAN, Ph.D., F.R.S.
C. D. HOWE, Ph.D.
J. B. McMURRICH, Ph.D., LL.D.
J. WATSON BAIN, B.A.Sc., Ph.D.
H. F. DAWES, M.A.
E. P. MATHEWSON, Esq.
W. H. SHAPLEY, Esq.

CONTENTS

Palaeozoic Fossils from a region southwest of Hudson Bay. (Plates I-VII) 3
W. A. Parks, Ph.D., F.R.S.C.

On *Clupea Pallasii* Cuvier and Valenciennes. (Plates VIII and IX) 97
C. McLean Fraser, Ph.D.

Ichthyological Notes (Plate X, Figs. 21-25) 109
C. McLean Fraser, Ph.D.

Submarine Boats (Plates XI-XVI) 119
Commander William Hovgaard.

Sir Sandford Fleming, K.C.M.G., LL.D., M. Inst. C.E., Lond., etc. (Plate XVII) 139
G. K.

Industrial Research in Canada 143
J. C. McLennan, Ph.D., F.R.S.

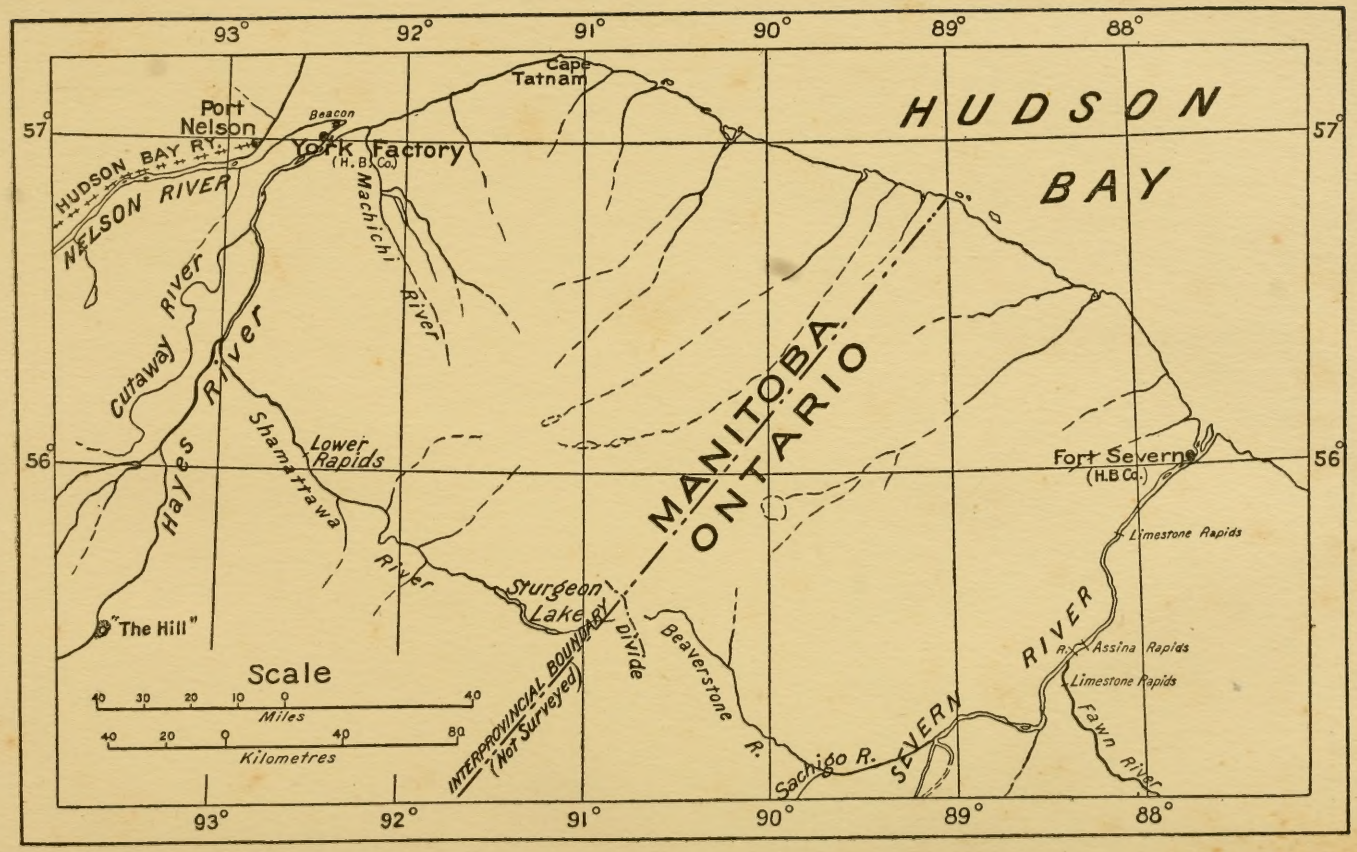
Fomes officinalis (Vill.), A Timber-Destroying Fungus (Plates XVIII-XXV) 185
J. H. Faull, B.A., Ph.D.

Agriculture in War-Time 211
Frank T. Shutt, M.A., D.Sc.

The Growth of Etch-Figures (Plates XXVI-XXVII) 230
William Harvey McNairn, B.A., Ph.D.

The Mining and Metallurgical Treatment of Molybdenum Ores in Canada 269
G. C. Mackenzie.

17205


93°
92°
91°
90°
89°
88°
57°
56°
HUDSON
BAY
Cape
Tatnam
Port
Nelson
Beacon
York Factory
(H.B.Co.)
HUDSON BAY RY.
NELSON RIVER
Machichi
River
Cutaway River
Hayes River
Shamattawa
River
Lower
Rapids
MANITOBA
ONTARIO
Fort Severn
(H.B.Co.)
Limestone Rapids
Sturgeon
Lake
Divide
"The Hill"
Beaverstone R.
Sachigo R.
SEVERN
RIVER
Assina Rapids
Limestone Rapids
Fawn River
INTERPROVINCIAL BOUNDARY
(Not Surveyed)
Scale
40 30 20 10 0 40
Miles
40 20 0 40 80
Kilometres

A2337

TRANSACTIONS

OF

THE ROYAL CANADIAN INSTITUTE.

PALAEOZOIC FOSSILS FROM A REGION SOUTHWEST OF HUDSON BAY.

A Description of the Fossils collected by Joseph B. Tyrrell, Esq., F.R.S.C., in the District of Patricia, Ontario, and in Northern Manitoba during the Summer of 1912.

By W. A. Parks, Ph.D., F.R.S.C.

(Associate Professor of Geology, University of Toronto.)

By Act of Parliament of Canada in the year 1912, a portion of the old District of Keewatin, estimated at 157,400 square miles, was added to the Province of Ontario. In the same year appeared a compilation of the literature bearing on this region which was published as the Second Part of the Twenty-first Volume of the Report of the Bureau of Mines of Ontario. This report, written by Professor W. G. Miller, Provincial Geologist, gives an excellent summary of the work hitherto done in this area, which is now embraced in the Province of Ontario under the name of the District of Patricia.

In April 1912, the Honourable the Minister of Lands, Forests and Mines of the Province of Ontario instructed Joseph B. Tyrrell, Esq., to perform certain duties regarding the details of boundary between the Provinces of Ontario and Manitoba and "finally to return home through that part of the District of Keewatin added by the Act of Parliament of last session to the Province of Ontario, and now known as the District of Patricia, obtaining such general information as to the character, resources and possibilities of this district as it might be possible to procure in the time available".

In the course of his investigations, Mr. Tyrrell collected a large number of fossils from the Silurian outcrops along the Severn river and its tributary the Fawn river. On the Manitoba side of the boundary, particularly at the lower rapids of the Shamattawa river, a number

of Ordovician species was obtained. In addition to the material from these definite horizons some few fossils were collected from the drift at the mouth of the Nelson river and in the vicinity of York.

Under the caption "Hudson Bay Exploring Expedition, 1912" Mr. Tyrrell published the results of his investigations in the First Part of the Twenty-second Report of the Bureau of Mines of Ontario. The fossils collected on the expedition had been submitted to me for examination and a preliminary account of these remains is contained in Mr. Tyrrell's report. The present paper is an attempt to present in more extended form a description of all the recognizable material collected by Mr. Tyrrell.

Nearly all the Silurian fossils and many of the Ordovician species are represented by casts only: this has made the identification of the forms difficult, and in many cases, doubtful. In fact, had the material been obtained from an accessible region, much of it would have been thrown away as indeterminable; but the remoteness of the area and the desire to furnish a full account of the *collection* has induced me to carry my determinations beyond the point justified under normal conditions. Mistakes have doubtless occurred, and science has possibly been burdened with more synonyms, but I have refrained from new specific names in many cases where I have little doubt a new species is represented, and have preferred to leave the form indeterminate until better specimens have been found. A complete disregard of this doubtful material would not have done justice to Mr. Tyrrell's work. It is to be understood, therefore, that this paper is an account of the *collection* and not a treatise on the *fauna* of the region.

The collection contains 132 distinct forms to which possibly a dozen more might be added: of these, 48 are ascribed to known species, and 31 are new to science. The remaining 53 species are described, and in some cases figured, but their preservation does not justify specific names, although many of them are probably new. An analysis of the collection is given on the following page.

The most notable feature of this list is the great preponderance of Gastropods and Cephalopods, and in this connection it may be noted that some unusually large forms occur. *Phragmoceras whitneyi* and *Euomphalopterus tyrrelli*, herein described, are of exceptional size for the genera to which they belong.

The general aspect of the fauna of the Severn and Fawn river Silurian indicates an horizon comparable with the Guelph of Ontario, and the Ordovician species of the Shamattawa river suggest the fauna of the Trenton. While presenting features characteristic of the Manitoba Trenton, the Ontario Trenton and the Trenton of Baffin Land, our

	Ordovician			Ordovician drift			Silurian			Silurian drift			Doubtful drift
	Known sp.	New sp.	Indet. sp.	Known sp.	New sp.	Indet. sp.	Known sp.	New sp.	Indet. sp.	Known sp.	New sp.	Indet. sp.	Indet. sp.
Porifera	..	1	..	..	..	..	..	..	..	..	..	..	..
Stromatoporoids	..	..	..	..	..	..	2	..	..	..	..	..	..
Actinozoa	3	1	1	..	..	..	9	2	3	1	..	..	2
Bryozoa	1	..	1	..	..	..	1	..	..	..	..	..	..
Brachiopoda	1	1	2	..	..	1	10	1	4	..	..	..	..
Gastropoda	1	4	..	..	..	1	10	8	18	..	..	..	..
Pelecypoda	..	..	..	..	..	3	1	1	..	..	..	..	..
Cephalopoda	3	5	3	..	..	1	..	5	9	1	1	..	2
Trilobita	..	..	1	..	..	1	2	..	..	..	..	..	..
Ostracoda	..	..	..	..	..	..	..	..	..	3	..	..	..
Total	9	12	8	..	..	7	35	17	34	5	1	..	4

assemblage seems to indicate a fauna differing somewhat from any of these.

The fossils herein described were presented to the Royal Ontario Museum of Palaeontology, Toronto, by the Hon. W. H. Hearst, who was Minister of Lands, Forests and Mines at the time Mr. Tyrrell's expedition was undertaken, and who is now Prime Minister of the Province of Ontario.

As Professor Miller has published (*op. cit.*) a summarized account of the general geology of the area, with references to the literature bearing on the subject, it will be unnecessary to repeat that information here, but it seems advisable to mention the chief palaeontological papers dealing with the Ordovician and Silurian faunae, not only of this immediate vicinity, but of Manitoba and the Arctic islands. The more important contributions are as follows:

AMI, H. M.—Appendix to "The Cruise of the Neptune", Govt. Printing Bureau, Ottawa, 1906.

KINDLE, E. M.—On some Palaeozoic Fossils from Baffin Land, Am. Jour. Sci. (4), Vol. II, pp. 455-456.

KINDLE, E. M.—The Silurian and Devonian Section of Western Manitoba, Geol. Sur. Can., Summary Rep. 1912, p. 247.

LAMBE, L. M.—Geol. Sur. Can., Ann. Rep., Vol. IX, p. 54 F, 1896.

LAMBE, L. M.—Appendix to "The Cruise of the Neptune". Govt. Printing Bureau, Ottawa, 1906.

McINNES, W.—Report on a Part of the Northwest Territories of Canada drained by the Winisk and Attawapiskat Rivers. Geol. Sur. Can., Publication No. 1080, 1909.

McINNES, W.—The Basins of the Nelson and Churchill Rivers. Geol. Survey, Can., Memoir 30 (No. 1225), 1913.

PARKS, W. A.—Notes on Silurian Stromatoporoids from Hudson Bay. Ottawa Naturalist, Vol. 22, pp. 25-29, 1908.

PARKS, W. A.—Silurian Stromatoporoids of America. Univ. of Toronto Studies, Geol. Series, No. 6, 1909.

PARKS, W. A.—Preliminary List of the Fossils collected by Joseph B. Tyrrell in the District of Patricia, etc. Bur. of Mines of Ont., 22nd Rep., pt. 1, 1913.

SALTER, J. W.—Appendix to Sutherland's Journal of Captain Penny's Voyage to Wellington Channel, etc., 1852.

SALTER, J. W.—On Arctic Silurian Fossils. Quart. Jour. Geol. Soc. Lon., Vol. IX, 1853.

SCHUCHERT, C.—On the Lower Silurian Fauna of Baffin Land. Proc. U.S. Nat. Mus., Bull. 22, pp. 143-177, 1900.

TYRRELL, J. B.—Report on the Doobaunt, Kazan and Ferguson Rivers. Geol. Sur. Can., Ann. Report, Vol. IX, p. 91 F, 1896.

TYRRELL, J. B.—The Hudson Bay Exploring Expedition, 1912. Bur. Mines, Ont., 22nd Rep., Pt. 1, 1913.

ULRICH, E. O.—On Sceptropora, with Remarks on Heliopora, etc. Am. Geologist, Vol. I, pp. 228-234, 1888.

ULRICH, E. O.—Bryozoa and Ostracoda from the Cambro-Silurian of Manitoba. Geol. Sur. Can., Cont. to Can. Micro-Palaeontol., Vol. I, 1889.

WHITEAVES, J. F.—Description of Eight new Species of Fossils from the Trenton Limestone of Lake Winnipeg. Can. Rec. Sci., Vol. VI, pp. 387-397, 1895.

WHITEAVES, J. F.—Fossils of the Galena-Trenton and Black River Formations of Lake Winnipeg and its Vicinity. Geol. Sur. Can., Palaeoz. Foss., Vol. III, Pt. 3, 1897.

WHITEAVES, J. F.—Descriptions of Eight new Species from the Cambro-Silurian Rocks of Manitoba. Trans. Royal Soc. Can., Vol. VII, Sec. IV, pp. 75-83, 1890.

WHITEAVES, J. F.—The Orthoceratidae of the Trenton Limestone of the Winnipeg Basin. Trans. Royal Soc. Can., Vol. IX, Sec. IV, pp. 77-90, 1892.

WHITEAVES, J. F.—Notes on the Gastropoda of the Trenton Limestone of Manitoba. Can. Rec. Sci., Vol. V, pp. 317-328, 1893.

WHITEAVES, J. F.—A recent Discovery of Rocks of the Age of the Trenton Formation at Akpatok Island, Ungava Bay. Am. Jour. Sci., Vol. VII, pp. 433-434, 1899.

WHITEAVES, J. F.—On some Silurian and Devonian Fossils collected by Dr. Bell in Manitoba and Hudson Bay. Can. Nat., New Series, Vol. IX, p. 315, 1880.

WHITEAVES, J. F.—On some Silurian and Devonian Fossils from Manitoba and Valleys of the Nelson and Churchill Rivers. Geol. Sur. Can., Rep. of Prog., 1878-79, pp. 45-51 C, 1880, 1881.

WHITEAVES, J. F.—Preliminary List of Fossils from the Silurian Rocks of the Ekwan River and Sutton Mill Lakes, Keewatin. Geol. Sur. Can., Ann. Rep., Vol. XIV, Pt. F., pp. 38-59, 1904.

WHITEAVES, J. F.—On the genus Trimerella, with Descriptions of two supposed new Species of that Genus from the Silurian Rocks of Keewatin. Ottawa Nat., Vol. XVI, pp. 139-143, 1891.

WHITEAVES, J. F.—Description of a new genus and species of Rugose Coral from the Silurian Rocks of Manitoba. Ottawa Nat., Vol. XVIII, pp. 113-114, 1904.

WHITEAVES, J. F.—The Fossils of the Silurian Rocks of Keewatin, Manitoba, the Northeastern Shore of Lake Winnipegosis, and the lower Saskatchewan River. Geol. Sur. Can., Pal. Fossils, Vol. III, Pt. 4, pp. 243-296, 1906.

WHITEAVES, J. F.—Notes on Cyrtoceras cuneatum. Ottawa Nat., Vol. XX, pp. 133-134, 1906.

WHITFIELD, R. P.—Observations on and Descriptions of Arctic Fossils. Am. Museum of Nat. Hist., Bull. 13, pp. 19-22, 1900.

The descriptions herein contained are compiled as follows:

I. Ordovician species.
II. Species from Ordovician drift.
III. Silurian species.
IV. Species from Silurian drift.
V. Species from the drift of doubtful age.

I.

ORDOVICIAN SPECIES

The following species were obtained chiefly from the lower rapids of the Shamattawa river, which enters Hudson Bay near Port Nelson. The horizon is Trenton, but the assemblage of fossils indicates a slightly different position from the Trenton of Baffin Land.

PORIFERA

AULOCOPIUM (AULOCOPELLA?) GIGANTEA, *sp. nov.*

Plate V, Figure 7.

This species is represented by a single fragment, 110 mm. long, 70 mm. wide and about 15 mm. thick. The curvature of the canals and the divergence of the skeletal elements indicate that the diameter could not have been less than 300 mm.

The polished vertical section of the specimen shows large concentric canals of about 3 mm. in width. The canals are not round, but elliptical, with the greater diameter in the plane of section: they are 2 to 3 mm. apart in the plane of section and rather less in the opposite direction. Smaller radial pores traverse the tissue at right angles to the larger concentric pores. The radiating skeletal elements appear to the number of 5 or 6 in the space of one mm.

There can be little doubt that this specimen represents a species of the genus *Aulocopium*, but its reference to the sub-genus *Aulocopella* is less certain. Regarding this sub-genus Rauff says: "Untergattung

Aulocopella. . . . Von *Aulocopium* dadurch verschieden, dass der Skeletradiant nicht an oder dicht über dem Fusspunkte, sondern wie z. B. bei den Astylospongiden inmitten des Spongienkörpers liegt".[1] It is manifest that this determinative feature cannot be ascertained in our fragment, but the striking resemblance to *Aulocopella winnipegensis* would suggest the sub-genus. This remarkable sponge was described by Dr. Rauff (*op. cit.*) from a specimen from Cat Head, Lake Winnipeg, submitted to him by Dr. Whiteaves, who refigures the species in the Third Volume of Palaeozoic Fossils (Page 145, Plate 16, Figures 1-3 and Figure 9, p. 146). On account of the great similarity of our specimen I am inclined to regard the section as passing vertically through one of the lobes of an *Aulocopella* resembling *A. winnipegensis*. The two species can scarcely be identical, for our form is very much larger and shows distinct radial pores which have not been observed in *A. winnipegensis*.

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 417 S. Royal Ontario Museum of Palaeontology.

ACTINOZOA

Cf. FAVOSITES ASPERA, *d'Orbigny*.

Cf. COLUMNARIA FRANKLINI, *Salter* sp.

FAVOSITES ALVEOLARIS, *Lonsdale*. Murch. Sil. Syst., p. 681, pl. 15 bis, figs. 1, 1a, 1b and 2, 2a, 1839.

FAVOSITES ASPERA, *d'Orbigny*. Prodr. de Paleont., Vol. I, p. 49, 1850.

FAVOSITES ASPERA, *Milne-Edwards and Haime*. Polyp. Foss. des Terr. Palaeoz., p. 234, 1851.

FAVOSITES ASPERA, *Milne-Edwards and Haime*. Brit. Foss. Corals, p. 257, pl. LX, figs. 3, 3a, 1855.

FAVOSITES ASPERA, *McCoy*. Brit. Pal. Foss., p. 20, 1855.

FAVOSITES PROLIFICUS, *Billings*. Can. Nat., 2nd series, Vol. II, p. 429, 1865; Cat. Sil. Foss. of Anticosti, p. 6, 1866.

FAVOSITES (?) CAPAX, *Billings*. Cat. Sil. Foss. of Anticosti, p. 6, 1866.

FAVOSITES NIAGARENSIS, *Rominger* (non *Hall*). Geol. Sur. Mich., Foss. Corals, p. 22, pl. V, fig. I, 1876.

FAVOSITES ASPERA, *Lebedeff*. Obersilurische Fauna des Timan, p. 8, pl. I, figs. 1, a, b, c, 1892.

FAVOSITES PROLIFICUS, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. II, p. 113, 1895.

FAVOSITES ASPERA, *Lambe*. Geol. Sur. Can., Cont. to Can. Pal., Vol. IV, pt. I, p. 4, 1899.

FAVOSITES ASPERA, *Parks*. Bur. Mines of Ont., 22nd Rep., p. 190, 1913.

FAVISTELLA FRANKLINI, *Salter*. Sutherland's Journal of Captain Penny's Voyage to Wellington Channel, etc., Vol. II, Appendix, p. CCXXIX, pl. 6, figs. 3 and 3a, 1852.

---

[1] Palaeospongiologie, Dr. Hermann Rauff, Palaeontographica, Vol. XLIII, p. 268 (392).

Portions of two coralla are represented in the specimens: these are each about 4 inches in diameter and are of identical structure except that the corallites are larger in one specimen than in the other.

The coarser specimen is part of a hemispherical or cake-shaped mass composed of polygonal, closely appressed tubes about 2.5 mm. in average diameter. The walls are thin and appear to be common to the contiguous tubes. Although the specimen is well preserved, there is no evidence of the presence of mural pores or septal spines. Straight or slightly arched tabulæ are well and regularly developed at intervals of rather less than one millimetre.

The finer specimen differs only in the size of the tubes which are 1.5 to 2 mm. in diameter. The tabulae are perfect, only slightly waving, and spaced at intervals of .5 mm.

Both specimens are so well preserved that the absence of pores and spines can scarcely be attributed to mineralisation, nevertheless such an assumption must be made if we are to place the specimen in any known genus or even family of Palaeozoic corals. If we assume the presence of pores in the angles of the corallites and a slight development of spiniform septa the forms are strikingly like *F. aspera*, particularly in view of the following remarks of Lambe in the work cited above: "Specimens of a *Favosites* have also been collected at East Selkirk and Lower Fort Garry, Manitoba, that are doubtfully referred to this species; they do not show the pores, although otherwise the structure is well preserved. The rocks at these localities have been assigned by Mr. Whiteaves to the Galena-Trenton, so that if, through the medium of other specimens from these places, the pores are found to be situated at the angles of the corallites, the downward extension of the range of *Favosites aspera* will be considerable".

By assuming the presence of very short septa our specimens approach very close to *Favistella* (*Columnaria*) *franklini*, Salter. I am inclined to favour this identification. As the original description in "Sutherland's Voyage" is somewhat difficult to obtain, it is reproduced in full below:

"*Favistella franklini*—Masses a foot in diameter composed of long polygonal tubes, nearly two lines broad, of very nearly equal size on the surface, the growth is by interposition of young tubes, which soon attain to the adult size. The walls of the tube are as thick in reality as those of the last species (*Favistella reticulata*), but appear much thinner from the absence of lamellæ: these are reduced to mere longitudinal striæ, seldom projecting at all into the tube, and in general scarcely visible to the naked eye. The diaphragms are very closely packed, about four in the space of a line throughout the largest specimen,

—those in the figured fragment are more distant, especially towards the base of the young tubes. They are seldom quite flat, usually a little waved up or down, as in the last species".

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
Nos. 287 S, 288 S, Royal Ontario Museum of Palaeontology.

STRIATOPORA, *sp. indet.*

Cf. FAVOSITES POLYMORPHA, *Salter* (*non Goldfuss*). Sutherland's Journal of Captain Penny's Voyage to Wellington Channel, etc., Vol. II, appendix, p. CCXXVIII, pl. 6, figs. 9, 9a, 1852.

The collection contains two specimens of a small branching coral, showing a maximum diameter of 15 mm. One specimen is badly water worn and cannot be relied upon for external characters, the other is less worn and shows the slightly oblique apertures, thick walls and sharp edges characteristic of *Striatopora*. The cells are about 2 mm. in diameter, but the calyces are too badly preserved to show the radiating striæ.

A vertical section shows that the walls of the tubes are at first thin and that they increase in thickness as they turn gradually out to the surface. Tabulæ are very faintly indicated, and mural pores cannot be made out, as the specimens are considerably silicified. In view of these imperfections it is manifestly impossible to ascribe the form to any known species or to attempt its full description. It is very likely that we are dealing with the same form ascribed by Salter (*op. cit.*) to *Favosites polymorpha*, Goldfuss, as the external appearance is very like that of the figures given by Salter.

Salter's description is in part as follows: "The tubes are by no means of equal size—numerous small ones occurring between the others. The edges are somewhat thickened. Internally the tubes are sometimes cylindrical and smooth, at others more prismatic. They are sometimes faintly striate inside. The pores occur in single rows at wide distances apart. The transverse diaphragms are not visible in these specimens.

"But another specimen, with all the same external characters as the rest, and having the internal diaphragms very plain and rather close, about two in the diameter of a tube, and the pores in two rows on each face, agrees well with *F. crassa* of McCoy."

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 297 S. Royal Ontario Museum of Palaeontology.

COLUMNARIA RUGOSA, *Billings* sp.

LITHOSTROTION STOKESI, *Milne-Edwards and Haime.* Polyp. Foss. des Terr. Palaeoz., p. 440, pl. 20, fig. 2, 1851.
PALAEOPHYLLUM RUGOSUM, *Billings.* Geol. Sur. Can., Rep. Prog. for 1857, p. 168, 1858.
COLUMNARIA ERRATICA, *Billings. Ibid.* p. 166, 1858.
DIPHYPHYLLUM STOKESI, *Whiteaves.* Geol. Sur. Can., Pal. Foss., Vol. III, pt. III, p. 152, pl. XVII, figs. 5, 5a, 5b.
COLUMNARIA RUGOSA, *Lambe.* Ottawa Naturalist, Vol. XII, p. 217, 1899.
COLUMNARIA RUGOSA, *Lambe.* Con. Can. Pal., Vol. IV, pt. II, p. 101, pl. III, figs. 3, 3a, 3b, 1900.
COLUMNARIA RUGOSA, *Parks.* Bur. Mines Ont., 22nd Rep., p. 190, 1913.

A well preserved fragment showing about fifty corallites. Lambe gives the corallites of this species a diameter varying from three to nine millimetres: the maximum diameter of our corallites is six millimetres with an average considerably less. Lambe also states that the tabulæ occur to the number of four in a distance of two millimetres: while this is true in parts of our specimen, a much wider spacing is observed in others. There can be little doubt, despite these trifling differences, that this specimen is referable to *C. rugosa.*

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 291 S. Royal Ontario Museum of Palaeontology.

STREPTELASMA *cf.* RUSTICUM, *Billings.*

Plate V, Figures 4 and 5.

STREPTELASMA CORNICULUM, *Milne-Edwards and Haime.* Polyp. Foss. des Terr. Palaeoz., p. 398, pl. 7, figs. 4, 4a, 4b, 1851.
PETRAIA RUSTICA, *Billings.* Geol. Sur. Can., Rep. for 1857, p. 168, 1858.
ZAPHRENTIS CANADENSIS, *Billings.* Geol. Sur. Can., Pal. Foss., Vol. I, p. 105, figs. 93a-c, 1862.
PETRAIA CANADENSIS, *Billings.* Geol. Sur. Can., Rep. 1863, p. 208, fig. 205.
STREPTELASMA CORNICULUM, *Nicholson.* Pal. Ont., p. 26, 1875, and Geol. Sur. Ohio, Vol. II, p. 218, 1875.
STREPTELASMA CORNICULUM, *Rominger.* Geol. Sur. Mich., Foss. Corals, p. 141 (pars), pl. LI, upper row, specimens from the Hudson River formation only, 1876.
STREPTELASMA RUSTICUM, *Lambe.* Geol. Sur. Can., Cont. to Can. Pal., Vol. IV, pt. II, p. 110, pl. VII, figs. 2, 2a and 3, 1900.
STREPTELASMA CORNICULUM, *Parks.* Bur. Mines Ont., 22nd Rep., p. 190, 1913.

The specimen in this instance is a single broken corallum showing neither calyx or apex: it is 41 mm. long and presents a diameter at the anterior end of 33 mm. The posterior diameter is 25 mm. The general form of the corallum in the portion preserved is nearly straight. The exterior is smooth and is apparently covered by a complete epitheca, as the septal markings are not to be observed.

A transverse section (Pl. V, Fig. 5) at about the middle of the specimen, where the diameter is 31 mm., shows 50 long primary septa which extend inwards for a length of 11 mm.: towards the centre they coalesce and lose their identity in a mass of reticulated tissue. Secondary septa appear between the primaries and extend inwards for 6 mm. This outer zone is thickened by deposits of calcareous matter and shows no structures besides the septa. Between the inner ends of the secondaries and the central area of reticulated tissue, inwardly curved dissepiments appear in the interseptal loculi. The transverse section, therefore, presents three well defined zones—an outer ring with primaries and secondaries, a middle zone with primaries and dissepiments and an inner reticulated area.

A longitudinal section (Pl. V, Fig. 4) shows no further structures in the outer zone. The intermediate area, as the section is not exactly median, shows the severed edges of some primary septa and upwardly directed dissepiments. On entering the central area the dissepiments assume a more horizontal direction and present, to some extent, the characteristics of tabulæ. This central area shows a rather indistinct arrangement of dissepiments and septa, and, on the whole, suggests a transition between the structure typical of *Streptelasma* and that which characterizes *Zaphrentis*. There is more evidence of irregularity in the vertical than in the horizontal elements of the reticulation.

In the preliminary report this specimen, together with others from the same locality, was referred to *S. corniculum*, Hall. The straight form of the corallum, its greater size, its smooth exterior, and the relatively long secondary septa, seem to bring the form closer to *S. rusticum*, Billings, as redefined by Lambe. The internal structure is very like that figured by Lambe, but the secondary septa are relatively longer and the internal structures of a coarser type in our specimen; nevertheless, in the absence of better material, the form may reasonably be ascribed to Billings' species.

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 285 S. Royal Ontario Museum of Palaeontology.

STREPTELASMA INTEGRISEPTATUM, *sp. nov.*

Plate V, Figures 1, 2 and 3.

This species is described from two very imperfect specimens which nevertheless present definite features not seen in species hitherto described.

The corallum is simple and conical, rather strongly curved at first, but almost straight in later stages of growth. The length of the concave side is 35 mm. and that of the convex side 56 mm. measured in a straight line from the apex. The diameter from the calyx rim on the concave side measured directly across is 27 mm.

The character of the calyx is somewhat doubtful, but it is probably of moderate depth, with a floor disposed at an oblique angle to the axis of the corallum. The centre of the floor is marked by a prominent elevation representing the extremity of a central zone of reticulated tissue. A fossula is probably present, although it was not observed in the specimens owing to the calyces being filled with matrix. The exterior is marked by very delicate transverse lines and faint septal furrows: both of these are so obscure that to the naked eye the exterior is quite smooth. Increase is effected by calycinal gemmation.

The transverse section shows a distinct tetrameral arrangement of the septa which are apparently of one order only. The thickened peripheral ends of the septa form an outer wall 2 mm. thick. It is possible that very short secondary septa are hidden in this wall, but no trace of their existence was observed. About 50 septa occur at a diameter of 25 mm. The cardinal septum is largely absorbed, and its position is clearly marked by an opening between the adjoining septa. On both sides of the cardinal septum the septa are rather short. The alar septa are long and the counter septum and those near it are long and rather crowded. On the cardinal side the septa do not reach the centre, but on the counter side the inner ends of the septa coalesce and with the dissepiments build up a zone of reticulated tissue. At a point nearer the apex a second transverse section does not show the above characteristic in so distinct a manner, as all the septa extend to the central spongy zone. Here also the septa are united by occasional curved dissepiments. Plate V, Fig. 2.

A tangential section shows the septa and the numerous downwardly arched dissepiments. Plate V, Fig. 3.

Median vertical sections show that the dissepiments are moderately flat or convex in the peripheral region, but that they turn upwards to join the central reticulated area. Plate V, Fig. 1 shows a considerable difference on the two sides: the right is the cardinal and the left the counter sides. The difference is in part due to the fact that the section is almost in the line of a septum on the left side, while on the right the septa are cut at a low angle.

This form is undoubtedly near *S. corniculum*, Hall, and I should ascribe it to that species except for the following points of difference: the smooth exterior, the absence of secondary septa, and the presence

of the sharply defined elevation on the floor of the calyx. The specimens have some resemblance to *Strephodes pickthornii*, Salter,[1] but they differ in the absence of longitudinal striæ on the outer surface and in their greater size. Our forms also are more elongate and present fewer septa for a given diameter.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 286 S. Royal Ontario Museum of Palaeontology.

BRYOZOA

MONOTRYPA CUMULATA, *Ulrich.*

MONOTRYPA (CHAETETES) CUMULATA, *Ulrich.* Geol. Sur. Minn., Pal. Vol. III, pt. 1, p. 307, pl. XXVII, figs. 26 and 27, 1895.
Cf. DIANULITES PETROPOLITANA, *Dybowski.* Die Chaetetiden der Ostbaltischen Silur-Formation, p. 24, pl. 1, figs. 4 and 5, 1877.
Cf. DIANULITES PETROPOLITANA, *Bassler.* U.S. Nat. Mus., Bull. 77, p. 232, Plate 2. figs. 4-6a; pl. 10, figs. 7-11; text figs. 129-132, 1911.

One fragment about 60 mm. by 45 mm. by 10 mm., apparently belonging to a sub-hemispherical polyzoarium. Tangential and vertical sections of this specimen were submitted to Dr. Ray S. Bassler of the United States National Museum, who has kindly communicated the following determination: "The bryozoan is closely related to *Monotrypa cumulata*, Ulrich, from the Mohawkian rocks of Minnesota. In my Baltic Province bulletin you will find this species listed as a synonym under *Dianulites petropolitana*. Your species is too little different to make even a good variety".

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 420 S. Royal Ontario Museum of Palaeontology.

ESCHAROPORA (?), *sp. indet.*

One small fragment showing round pores arranged diagonally. Four occur in the space of one mm. The surface is worn and identification therefore impossible.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 412 S. Royal Ontario Museum of Palaeontology.

[1] Sutherland's Journal of Captain Penny's Voyage to Wellington Channel, etc., Vol. II, Appendix, p. CCXXX, pl. 6, fig. 5, 1852.

BRACHIOPODA

RHYNCHOTREMA (?), *sp. indet.*

RHYNCHOTREMA CAPAX, *Conrad, Parks.* Bur. Mines, Ont., 22nd rep., p. 190, 1913.

One imperfect ventral valve, ventricose with moderately elevated median fold. The fold seems to be marked by a distinct central plication and by one other fainter plication on each side of the major one. Seven or eight ribs occur between the median fold and the angles of the shell. In the preliminary report this shell was referred provisionally to *R. capax*: while there is a superficial resemblance I fear the specimen is too imperfect to justify the comparison.

Schuchert records *Rhynchotrema minnesotensis*, Sardeson, *R. inaequivalvis*, Castelnau, and *R. inaequivalvis subtrigonalis*, Hall, in the Trenton of Baffin Land.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 404 S. Royal Ontario Museum of Palaeontology.

Cf. DINORTHIS PECTINELLA, *Emmons* sp.

ORTHIS PECTINELLA, *Emmons.* Geol. Sur. N.Y., Rep. 2nd Dist., p. 394, fig. 2, 1842.

Several broken and decorticated specimens, quite impossible of identification: they are referred to this species with the greatest doubt. Compare also *Orthis* (*Plectorthis*) *plicatella* which Schuchert states is a common fossil in the Trenton of Baffin Land.[1]

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 405 S. Royal Ontario Museum of Palaeontology.

STROPHOMENA (?) TETRASTRIATA, *sp. nov.*

Plate IV, Figure 16.

One partially worn ventral valve which is made the type of the species and two other shells similar in size and shape but lacking the characteristic markings.

The type is 25 mm. wide and 15 mm. long. The beak extends slightly posterior to the cardinal line, and the anterior margin is strongly inflected. The surface is marked by four distinct but delicate elevated ribs, two on each side of the median line, with a greater interval between the pairs. Between the ribs, the surface is marked by very delicate, anteriorly curved, concentric striæ, which are also seen beyond the ribbed area, but which do not extend to the lateral margins of the shell.

[1] Proc. U.S. Nat. Mus., Bull. 22, 1900.

The general shape of the shell and the strongly inflected anterior margin suggest the genus *Leptaena*, but the concentric rugosities characteristic of that genus are not present. With no knowledge of the interior the form is provisionally referred to *Strophomena*. In the preliminary description the species was compared with *S. julia*, Billings,[1] with which it is doubtless related. Billings' species, however, has more numerous prominent striae or ribs, and instead of the concentric markings between the major ribs it has fine radial striations.

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 403 S. Royal Ontario Museum of Palaeontology.

RAFINESQUINA, *sp. indet.*

RAFINESQUINA LATA, *Whiteaves, Parks*. Bur. Mines of Ont., 22nd Rep., pt. I, p. 190, 1913.

The collection contains a fragment of a large Strophomenoid shell which bears some resemblance to Whiteaves' species, but a close examination indicates that its reference to that species is not justified. The shell was possibly 40 mm. long, but its width is not revealed. The specimen shows only the median portion of the pedicle valve, which is strongly arched from umbo to anterior margin and also transversely with a broad but faintly marked median fold. The striae are of two orders, fine and coarse, but there is no regular arrangement of the two kinds: in places they are not to be differentiated. The shell is punctate, and the cast of the interior is marked by vascular sinusus, particularly in the mid-anterior region. The brachial valve is concave and well set into the pedicle valve, but none of its structural features are revealed.

The large size of this shell, its surface markings and its horizon suggest *R. lata*, but its arcuate outline, particularly in the transverse direction, seems to prohibit its reference to that species. The loss of the cardinal angles makes its specific identification doubtful, and I therefore prefer to leave it for the present as an indeterminate species.

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 415 S. Royal Ontario Museum of Palaeontology.

GASTROPODA

HORMOTOMA ACUMINATA, *sp. nov.*

Plate IV, Figure 3.

HORMOTOMA *sp.*, *Parks*. Bur. Mines of Ont., 22nd Rep., pt. 1, p. 190, 1913.

This species is founded on a cast of the interior showing five whorls. In the drawing the upper part of the spire is restored.

[1] Geol. Sur. Can., Palaeoz. Foss., Vol. I, p. 127, fig. 105a and b.

The total height is about 60 mm., while the width of the body whorl is only 18 mm. The whorls are evenly rounded and the sutures rather deeply impressed. The aperture is not well shown, but it appears to be narrow and moderately elongate. There are probably twelve whorls in all. A second broken portion showing two whorls probably belongs to this species and indicates a somewhat greater size, as the larger whorl is about 20 mm. in diameter. The sutures, however, are not as deep and the whorls are flatter: it may possibly represent another species.

H. acuminata is of the type of *H. gracilis*, and except for its much greater size approaches close to some of the varieties of that species: it also resembles *H. salteri*, Ulrich.

Ami has listed two species of *Hormotoma* from Beechey island as *H. arctica* and *H. affinis*, but as they are from a horizon probably much higher, it is not likely that the present species is identical with either.[1]

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 363 S. Royal Ontario Museum of Palaeontology.

The collection contains also a fragment of a body whorl of a *Hormotoma* indicating a much larger shell than the above. Ordovician, Shamattawa river.

No. 384 S. Royal Ontario Museum of Palaeontology.

HOLOPEA MEDIA, *sp. nov.*

Plate IV, Figure 4.

This species is founded on one broken cast of the interior; as it is distinctly different from any other of the specimens from this horizon, I venture to ascribe a specific name. The general shape of the whorls and the nature of the spire are fairly well shown, but there is no information available as to the surface markings, the aperture, or the umbilicus: the generic position must therefore be left in doubt, but the character of the whorls suggests *Holopea*.

The maximum width of the specimen is 40 mm. and its height to the top of the third whorl about 31 mm. The whorls are fairly evenly rounded on the outer side, but there is a slight degree of flattening on the upper lateral aspect which is more pronounced towards the aperture. The whorls expand rapidly, the body whorl being relatively very large and those of the spire being impressed to about a third of their height in the whorl below. The cast shows no evidence of surface markings of any kind. This form is remarkably like *Holopea guelphensis*, Billings, from the Guelph of Ontario, but it cannot be identical at the present horizon.

[1] "The Cruise of the Neptune", Appendix IV, pp. 329 and 330, 1906.

This form must be compared with *H. borealis*, listed by Ami but without description in "The Cruise of the Neptune".

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 361 S. Royal Ontario Museum of Palaeontology.

TROCHONEMA UMBILICATUM, *Hall* sp.

PLEUROTOMARIA UMBILICATUM, *Hall.* Pal. New York, Vol. I, pp. 43 and 175, 1847.
TROCHONEMA UMBILICATA, *Salter.* Geol. Sur. Can., Can. Org. Remains, Dec. 1, p. 27, pl. VI, fig. 3, 1859.
TROCHONEMA UMBILICATUM, *Ulrich.* Geol. Sur. Minn., Palaeon., Vol. III, pt. II, p. 1047, pl. LXXVII, figs. 1-8, 1897.

Seven specimens, all casts, showing some variation. They are ascribed to this species with considerable certainty.

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 360 S. Royal Ontario Museum of Palaeontology.

MACLUREA SUBOVATA, *Parks.* (*nom. prov.*)

Plate VII, Figures 4 and 5.

MACLUREA SUBOVATA, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 190, 1913.

It is with considerable hesitation that a new species is established for this *Maclurea* which is represented in the collection by one good cast and several fragments. It cannot be denied that the specimens show considerable resemblance to *M. logani*, Salter, and to *M. bigsbyi*, Hall. After careful comparison, however, I am unable to ascribe the forms with any certainty to the species mentioned, and until better material is secured I am of the opinion that the specimens are worthy of a provisional name.

The most perfect specimen, which I think is nearly complete, although the aperture is not shown, measures about 65 mm. in maximum diameter. Only two distinct whorls are seen, but there is evidence of a third very small initial whorl. The shell is thick and partly worn away on the under (flat) surface, but judging from the cast of the interior, the most striking peculiarity is the considerable convexity shown by the under surface of the whorls.[1] The outer side of the volutions is characterised by a rather straight outline which is more pronounced towards the aperture. The umbilicus is about 15 mm. in diameter. The measurements of the outer whorl nearest the aperture are as follows: Maximum

[1] Following Ulrich, the flat side is regarded as the base; the "umbilicus" therefore is really an inverted spire.

height from the umbilical edge to the inferior lateral angle—40 mm. Height from the superior external to the inferior internal edge—33 mm. Width measured at right angles to the outer sloping side—25 mm. These figures are slightly greater than those indicated in Plate VII, Figure 5, which is prepared from a section not passing close to the aperture. The form of the aperture differs from the cross section shown in the figure, as the inner lip is drawn out giving a more rectangular appearance to the top.

The specimens show no evidence of lines of growth or external ornamentation of any kind.

The few and rapidly expanding whorls separate this species sharply from forms like *M. magna*, but this very feature suggests *M. logani;* in fact, the character of the coiling is so like that of *M. logani*, and the general resemblance of some of our forms is so striking that I was at first inclined to ascribe the specimens to that species. A further resemblance is shown in the greater height as compared with the width of the whorl, and even the convexity of the under side is presented, but probably in a less distinct manner, by *M. logani*.[1] On the other hand there are some striking points of difference shown by our specimens—the straight outline of the outer aspect of the whorl, the sharper inferior lateral margin, and the very much wider umbilicus. Our specimens may be distinguished from *M. bigsbyi* by the greater convexity of the under sides of the whorls and the straighter lateral outline. The whorls seem to expand more rapidly than in *M. bigsbyi*, and the relative height of the whorl is greater. Schuchert recognizes *M. crassa*, Ulrich and Schofield in the Trenton of Baffin Land: although our form is similar, I cannot regard it as belonging to this species.

Whiteaves describes a species of Maclurea from the second and third limestone rapids of the Nelson river which he compares with *M. bigsbyi*. This form, however, cannot be co-specific with our specimens, as Whiteaves emphasizes the fact that the whorl is one-third greater in width than in height.[2]

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 351 S. Royal Ontario Museum of Palaeontology.

---

[1] Geol. Sur. Can., Palaeon. Decade I, p. 7, pl. I.
[2] Geol. Sur. Can., Rep. 1878-79, p. 48 C.

MACLUREA ACUTA, *sp. nov.*

Plate VII, Figures 1 and 2.

MACLURINA MANITOBENSIS ACUTA, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 190.

The only specimen of this species has a maximum diameter of nearly 100 mm. (The cast is 95 mm.). The vertical height of the deepest part preserved is 35 mm. Three whorls are shown, the inner one being extremely small. The under side is flat and slightly concave in the centre. The lower aspect of the whorls is very slightly convex, but this appearance would be greatly increased in the cast and the sutures would be quite deep. The actual width of the umbilicus is 18 mm. and its greatest width from summit to summit of the body whorl is 35 mm. The inferior margin of the whorls is acute, with a slight but distinct depression just above the angle. The outer aspect shows a decided slant with a slight convexity to the summit of the whorl. The measurements of the *cast* of the outer whorl nearest the aperture are as follows:

Vertical height—33 mm.

Width on the flat side—35 mm.

Width at right angles to the outer side—28 mm.

Although the shell is very well preserved on the base there is no indication of lines of growth or of ornamentation.

In the preliminary report this shell was made a variety of *Maclurina manitobensis*, Whiteaves,[1] which it strongly resembles in the character of the coiling and in the shape of the whorls. Although the aperture of our specimen is not shown, it is nevertheless fairly complete and indicates a much smaller size than that of *M. manitobensis*, and although the shell is well preserved on the flat side there is no indication of the periodic arrests of growth mentioned by Whiteaves, nor is any sign to be seen of the revolving lines and transverse costæ on the upper side, although a small portion of the shell is preserved. A comparison with specimens in the Royal Ontario Museum indicates a slightly greater rate of expansion in the whorls of the present example. I am by no means convinced that my original diagnosis was wrong, but as surface ornamentation is of prime importance in *M. manitobensis*, and as this ornamentation is not shown by our specimen, it is perhaps better to describe the present example as a distinct species, more particularly as Whiteaves' species has been removed to another genus, *Maclurina*, on the basis of the structure of the operculum—a feature which cannot be ascertained for the present example. *Maclurina manitobensis* is common in the Trenton of Silliman's Fossil Mount, Baffin Land, which is an additional argument for the identity of the present form.

[1] Trans. Royal Soc. Canada, Vol. VII, sec. IV, p. 75, pl. XII, pl. XIII, figs. 1 and 2.

The much greater slant of the outer side of the whorl and the more acute peripheral angle separates this form from *M. subovata*; the large umbilicus distinguishes it from *M. logani*. The sharply angulated periphery and the flattening of the outer side of the volutions on the convex side separate it from *M. bigsbyi*.

This form may possibly be identical with the *Maclurea* described by Whiteaves from the Nelson river (See page 20).

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 350 S. Royal Ontario Museum of Palaeontology.

CEPHALOPODA

ORTHOCERAS (THORACOCERAS) LEPIDODENDROIDES, *Parks*.

Plate II, Figure 4.

ORTHOCERAS LEPIDODENDROIDES, *Parks*. Bur. Mines of Ont., 22nd Rep., pt. I, p. 190, 1913.

The species is founded on a single cast of a portion of a longicone. The specimen is 75 mm. long and shows portions of 8 camerae: it has been badly crushed and now measures 60 mm. by 30 mm. If round its diameter would be 45 mm. The outline was probably ovate with a greater diameter in one direction. The septa are somewhat irregularly spaced, but the interval would average about 6 mm. In the crushed form the specimen shows evidence of flexuous sutures with low lobes and saddles, but this appearance may be entirely due to deformation.

The one remarkable and characteristic feature is that the whole surface of the cast is raised into blunt nodes arranged in a diagonal manner around the cone. These nodes are 4 to 6 mm. apart and besides the diagonal arrangement they are disposed in rows on each camera. While this latter statement is generally true, there is evidence in certain parts of the specimen that the nodes are independent of the cameræ. The drawing is much restored, as the ornamentation has been destroyed by weathering in certain parts: the nodes have been restored with rather too great regularity with respect to the cameræ. The nodes are blunt, from 4 to 5 mm. long, and wider anteriorly.

The genus *Orthoceras*, as now defined, is confined to forms with a smooth shell: it would appear that the present form was ornamented with obliquely arranged spines of which the nodes on the cast are the internal impressions. I am aware of no genus into which the specimen would properly fall, but as my literature is by no means complete, I hesitate to create a new genus. The genus *Thoracoceras*[1] includes longi-

[1] Eich., Bull. Soc. Imp. de Nat. de Mosc., p. 761, 1844.

cones in which the ridges become spiny, or are roughened by the prominence of the transverse striæ or ridges. This unique species is provisionally referred to Eichwald's genus.

Named on account of the striking resemblance of the cast to a stem of *Lepidodendron*.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 321 S. Royal Ontario Museum of Palaeontology.

ORTHOCERAS, *sp. indet.*

Two fragments of orthoceracones.

One fragment shows a body chamber about 44 mm. long, and portions of three camerae. The transverse section is elliptical, 25 mm. by 28 mm. at the third septum. Septa about 5.5 mm. apart. No siphuncle preserved.

The second fragment is from a smaller individual of possibly the same species; it is 45 mm. long, elliptical in section, 25 mm. by 20 mm. at the anterior end.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 333 S. Royal Ontario Museum of Palaeontology.

ACTINOCERAS, *Bronn.*

ACTINOCERAS, *Bronn.* Lethaea Geognostica, Zweite Aufl., Band. I, p. 97, 1837.
ACTINOCERAS, *Hyatt.* Proc., Boston Soc. of Nat. Hist., vol. XXII, p. 272, 1884.
ACTINOCERAS, *Foord.* Cat. Foss. Ceph., Brit. Mus., p. 164, 1888.

The characteristics of the genus are described in the above works: it is unnecessary to repeat here the details of structure. Of true *Actinoceras* or the modified form, *Huronia*,[1] our collection contains at least eight distinct species, which in most cases are represented by siphuncles only or by siphuncles with a fragment of the septate shell.

ACTINOCERAS BIGSBYI, *Bronn.*

Plate VI, Figure 7.

ORTHOCERAE, *Bigsby.* Trans. Geol. Soc., ser. 2, Vol. I, p. 198, pl. XXV, figs. 1 and 2 (excl. fig. 3), 1824.
ACTINOCERAS BIGSBYI, *Bronn.* Lethaea Geogn., Band I, p. 98, Taf. I, fig. 8 (after Bigsby), 1837.
ACTINOCERAS BIGSBYI, *Foord.* Cat. of Foss. Ceph., British Museum, p. 168, 1888. (For extended synonomy see this article.)
?ACTINOCERAS BIGSBYI, *Whiteaves.* Trans. Royal Soc. Can., Vol. IX, sec. IV, p. 84, pl. X, fig. 2, 1891.
ACTINOCERAS BIGSBYI, *Parks.* Bur. Mines of Ont., 22nd Rep., p. 191, 1913.

[1] Trans. Geol. Soc., ser. 2, Vol. I, pt. II, explanation of pl. XXVIII, 1824.

Our specimen is a fragment of the camerate shell about 120 mm. long: it is 65 mm. in diameter at the anterior end, and 47 mm. at the posterior extremity. It is possible, but not certain, that the shell was somewhat elliptical, measuring 65 by 50 mm. anteriorly and 47 by 40 mm. posteriorly. The rate of tapering indicated by these figures agrees fairly well with that given for *A. bigsbyi*. The external characteristics of the shell are not well shown, but it is probably smooth. I am unable to see "the longitudinal, undulated, fine, thread-like lines" of Hall.

The septa are 10 mm. apart, strongly curved orad: they are thin and delicate in structure.

The siphuncle is large, possibly 27 mm. in diameter at the smaller end of the specimen, but as some deformation has occurred, the exact diameter cannot be stated. The siphuncle is situated very close to one side of the shell.

The structure of the siphuncular sheath is very exact and persistent. In vertical section the inner ends of the septa are seen to extend directly apicad, forming an annular funnel for half the interseptal distance. In the posterior half of the interspace the siphuncle swells out into evenly rounded rings. This definite structure is not emphasised by authors in the descriptions of *A. bigsbyi*, and on this account I was inclined to ascribe our specimen to some other species. Bigsby's original figures, however, point strongly to this type of siphuncle.[1] Barrande's revision of the species shows that the swelling is located in the posterior part of the interseptal space, but his drawings do not emphasize the directly backward inflection of the septa into tubular necks.[2]

The endosiphuncle is not preserved, but the whorls of radial tubuli ("verticillations" of Stokes) are admirably preserved, and project from the inner sides of the nummuloidal rings almost at right angles. These structures must have been strongly calcified to withstand the vicissitudes to which the specimen has been subjected. The presence of these structures outweighs any objection based on the exact form of the siphuncular segments, which, considered alone, would suggest *Orthoceras* (*Actinoceras*) *anticostiense*, Billings, from the Upper Ordovician of Lake St. John (See plate 434, Figs. 9 and 10, Système Silurien de la Bohême).

My examination of this specimen has induced me, with great reluctance, to doubt Whiteaves' recorded occurrence of the species at Lower Fort Garry. If the form figured by Whiteaves is really *A. bigsbyi* we must entirely recast our conception of the species. (Royal Soc. Can., *op. cit.*).

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 308 S. Royal Ontario Museum of Palaeontology.

---

[1] Trans. Geol. Soc., ser. II, Vol. I, pl. XXV, figs. 1 and 2, 1824.

[2] Systême Sil. de la Bohême, pl. 437, figs. 10-16, 1870.

ACTINOCERAS *cf.* BIGSBYI, *Bronn.*

Plate VI, Figure 6.

One broken fragment showing only the siphuncle and the inner parts of the septa. Septa somewhat variably spaced but averaging 9 mm. apart. Siphuncle about 22 mm. in diameter evenly expanded in the posterior part of the interseptal space. The septa in contact with the posterior aspect of the rings, but separated from the anterior aspect by inwardly curved septal necks. In vertical section the outer, anterior wall of the nummuloidal expansion is broken in each segment, suggesting a communication between the interior of the siphuncle and the cameræ. No endosiphonal structures preserved.

This specimen, in all probability, is to be referred to *A. bigsbyi*: it closely resembles some of Barrande's figures of that species, but is distinctly different from the other specimen which I have referred to *A. bigsbyi* (Page 23), in that the septal necks, before expansion, are much shorter and pass less abruptly into the nummuloidal rings. The spacing of the septa and the size and shape of the siphuncle are almost exactly the same as in the figure given by Foord (Cat. Foss. Ceph., Brit. Mus. p. 104, Fig. 21).

If the characteristic radial tubuli could be seen in the present example, there could be no hesitation in ascribing it to *A. bigsbyi*, and were it not for the distinct evidence of cylindrical structure in the anterior part of the siphuncular rings shown in Bigsby's original figures, I should consider this specimen nearer to *A. bigsbyi* than the one described on page 23.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 315 S. Royal Ontario Museum of Palaeontology.

ACTINOCERAS RICHARDSONI MAGNUM, *Parks*, var.
Cf. ACTINOCERAS RICHARDSONI, *Stokes.*

Plate II, Figure 1.

ACTINOCERAS RICHARDSONI, *Stokes.* Trans. Geol. Soc., ser. 2, Vol. V, pt. 3, p. 708, pl. LIX, figs. 2 and 3, 1840.

CONOTUBULARIA CUVIERI, *Troost.* Mem. Soc. Geol. de France, tom. III, Ime. partie, p. 88, pl. 9, fig. 1, 1838.

ORTHOCERAS (ACTINOCERAS) RICHARDSONI, *Barrande.* Syst. Sil. de la Bohême, Vol. II, Texte III, p. 734, pl. CCXXXIV, figs. 2 and 3, 1847.

ACTINOCERAS RICHARDSONI, *Foord.* Cat. Foss. Ceph., Brit. Mus., p. 172, 1888.

ACTINOCERAS RICHARDSONI, *Whiteaves.* Trans. Royal Soc. Can., Vol. IX, sec. IV, p. 83, pl. IX, figs. 1, 2 and 2a, 1891.

ACTINOCERAS RICHARDSONI MAGNUM, *Parks.* Bur. Mines of Ont., 22nd Rep., p. 191, 1913.

Stokes' original description of this species is as follows: "In this the tube is small; it is surrounded by numerous laminae or plates, filling up the siphuncle; but it is difficult to determine their nature. The external shell is slightly conical in form. From Lake Winnipeg, in yellowish-white limestone much resembling that from Igloolik."

Stokes' figures show a siphuncle of about 28 mm. in diameter for a shell diameter of 53 mm. The nummuloidal rings are evenly rounded and fill the whole space between the septa, which are 8.5 mm. apart. The figures also show an irregularity in the development of the rings.

Foord (*op. cit.*) gives the spacing of the septa as 8 mm. at a shell diameter of 75 mm. He emphasises the vertical calcareous lamellae and the strongly orad curvature of the septa.

Whiteaves (*op. cit.*) states that the relative size of shell and siphuncle varies, though the maximum diameter of the latter is usually more than half that of the former. The posterior segment shown in his figures measures 36 mm. in breadth by 9 mm. in height and the anterior segment is 47 mm. in width by 10 mm. in height: ten segments intervene between these two.

The present specimen consists of a fragment 150 mm. long and 120 mm. wide, showing parts of 16 septa and 17 nummuloidal siphuncular rings. The maximum diameter of the siphuncle is 55 mm. at a point where the shell is probably 120 mm. in diameter. While it is hazardous to state definitely the size of the shell in a broken specimen such as this, it would appear that the siphuncle is somewhat less than half the diameter of the shell. Whiteaves' figures show the siphuncle to be within 6 mm. of the shell at a siphuncle diameter of 49 mm. and a shell diameter of 83 mm. Our specimen shows a minimum distance of 15 mm. between the siphuncle and the shell at a siphuncle diameter of 55 mm. These figures are not contradictory if we consider that our fragment is more orad than that referred to by Whiteaves. The relation between the height and width of the siphuncular segments is somewhat variable, but averages about 8 to 53; in the type figure this ratio is 8.5 to 28, and in Whiteaves' example it is 9 to 26 posteriorly and 10 to 47 anteriorly. It is apparent from Whiteaves' figures that the segments are relatively wider orad. Between the type, Whiteaves' example and our specimen, there is a discrepancy in these figures which may in part be explained by the different positions of the specimens relatively to the whole shell. Nevertheless, this difference is one reason for making a new variety of our specimen.

The septa arch strongly forward, particularly on the siphonal side, and occur to the number of 16 in a distance of 130 mm. The siphuncular funnels are short and extend about 2 mm. apicad. The inner parts of

the septa and the funnels appear to be double in correspondence with the general character of *Actinoceras*.

The endosiphuncle tapers rapidly, showing a diameter of 35 mm. at the anterior end and 12 mm. at the posterior end: its surface is finely striated longitudinally and it is drawn out into ridges between the septa. Tubuli arise from or near these ridges and pass directly outward into the nummuloidal rings which they appear to penetrate. The rapid tapering of the endosiphuncle is a feature not described for *A. richardsoni*, and constitutes a second reason for establishing a variety. The nummuloidal rings are somewhat irregularly developed, but are fairly evenly rounded, filling the whole interseptal space, and with the septa in contact with their posterior aspect for a considerable distance outwards.

Calcareous deposits form concretionary layers around the septal necks. Similar material is deposited around the endosiphuncle with the result that, with the shrinking of the endosiphuncle posteriorly, the whole space between the endosiphuncle and the siphuncle is filled with dense calcareous tissue.

I regard this specimen as related to *A. richardsoni* for the following reasons: The average septal spacing, the calcareous investment of the endosiphuncle, the somewhat irregular development of the nummuloidal rings, the well marked endosiphuncle, the strongly arched septa, and the direct outward course of the tubuli.

A distinct variety is indicated by the following points: The relatively greater width of the siphuncular segments to their height, the relatively smaller siphuncle compared with the width of the shell, and the rapidly tapering endosiphuncle. This latter fact may, however, be due entirely to the fact that our specimen probably represents a portion of the shell just posterior to the living chamber.

Locality—Mouth of Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 309 S. Royal Ontario Museum of Palaeontology.

HURONIA SEPTATA, *sp. nov.*

Plate V, Figure 8.

Our collection contains one broken siphuncle presenting part of the exterior and a longitudinal section which unfortunately is not median.

The fragment is 112 mm. long and shows six segments, making the average height of the segment 18.66 mm. The outline of the ring is a sigmoidal curve with the broader part anterior. The greatest diameter of the anterior ring is 40 mm. and the least diameter 28 mm.

The interior of the siphuncle shows about 20 longitudinal plates, radiating from a central endosiphuncle, which, however, is inferred but not observed. This internal support for radiating tubuli is very different from that of other species, in which it seems to take the form of annular membranous or calcareous expansions.

The height of the segments and the nature of the outline are very like those of *Huronia turbinata*, Stokes (Trans. Geol. Soc., Ser. II, Vol. I, Pt. II, explanation of Plate XXVIII, Fig. 3: and Page 203, Species III of Bigsby), but our specimen is relatively much wider.

An example in the Royal Ontario Museum referred to *H. turbinata* measures as follows: Height of segment 19 mm., greatest width 30 mm.; least width 18 mm. It is to be concluded that our specimen is of the same general type as *H. turbinata* but that it is not co-specific. The general assemblage of fossils at the Lower rapids of the Shamattawa river indicates Ordovician rocks: if the present specimen was really obtained *in situ*, the range of the genus *Huronia* is considerably extended, for it has hitherto been reported only from the Niagara group of North America.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician?
No. 312 S. Royal Ontario Museum of Palaeontology.

CYCLOCERAS (?), *sp. indet.*

Plate II, Figure 7.

One fragment of a cast: 25 mm. long, 15 mm. in diameter at anterior end and 14 mm. at posterior end. Surface marked by oblique and sharp crested annulations about 3 mm. apart. Straight or slightly coiled. A vertical section shows no internal structures.

As the test is not preserved, even the generic position of this fragment is doubtful, but it would fall under *Cycloceras*, *Spyroceras* or other related annulated genera.

The specimen bears some resemblance to *Spyroceras meridionale*, Whiteaves,[1] from the Silurian of Stonewall, Manitoba. Our form differs in the less rapid taper and the more uniform distance apart of the annulations.

The specimen bears considerable resemblance to *Cyrtoceras nitidium*, Barrande, from Etage E of Bohemia,[2] but perhaps the most striking comparison may be made with *Orthoceras anellum*, Conrad,[3] from the

[1] Geol. Sur. Can., Palaeoz. Foss, Vol. III, p. 281, pl. 30, fig. 9.

[2] Systême Silurien de la Bohême, pl. 198, figs. 21-35.

[3] Proc. Acad. Nat. Sci., Phil., 1843, p. 334; Pal. N.Y., Vol. 1, p. 202, pl. XLIII, fig. 6; Geol. Rept. Wisconsin, Vol. I, p. 442, 1862; *Ibid.*, Vol. IV, p. 226, pl. VII, fig. 13, 1882.

Trenton limestone of Wisconsin. If our specimen were more perfect, its reference to this species might be justified. Assuming a slight deformation whereby the annulations have been rendered oblique, our form might be compared with *Orthoceras olorus baffinensis*, Schuchert, from the Trenton of Baffin Land.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 332 S. Royal Ontario Museum of Palaeontology.

MELOCERAS, *sp. indet.*

Plate II, Figure 5.

Two fragments of a rather rapidly tapering, laterally compressed cyrtocone. The curvature is slight and the form is apparently exogastric. The fragments are about 60 mm. long and show a greater (dorso-ventral) diameter of 32 mm. at the anterior, and 23 mm. at the posterior end.

Nine cameræ are shown with a gradually decreasing width towards the posterior. On the convex side the first camera has a width of 6 mm. and the ninth a width of 3.5 mm. The sutures arch strongly forward on the siphonal (convex) side.

The rather slight curvature and the lateral compression of the shell suggest the genus *Meloceras* as emended by Foord. *Oncoceras articum*, Schuchert, from the Trenton of Baffin Land, appears to be a related form, but I cannot regard our specimen as of that species.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.
No. 328 S. Royal Ontario Museum of Palaeontology.

POTERIOCERAS TYRRELLI, *Parks.*

Plate II, Figure 2.

POTERIOCERAS TYRRELLI, *Parks.* Bur. of Mines of Ont., 22nd Rep., pt. 1, p. 191, 1913.

The species is founded on two specimens from the lower rapids of the Shamattawa river and on a photograph taken by Mr. Tyrrell of a third specimen of which he was unable to obtain possession.

The best preserved specimen from which the accompanying drawing was chiefly made shows a cast of the chamber of habitation and of nine air chambers. The whole shell is sac-shaped with a slightly greater convexity of the siphonal or ventral side: the shell is therefore to be described as exogastric. The transverse section is ovate and slightly compressed on the ventral side. The maximum diameter is at the

second camera, from which point the shell contracts anteriorly, but presents a sharp outward reflexion with crenulation at the aperture. The measurements of this specimen are given in column 1 below: those of the second specimen appear in column 2.

	1	2
Dorso-ventral diameter at second septum..	48 mm.	56 mm.
Lateral diameter at second septum.....	37 mm.	44 mm.
Dorso-ventral diameter at ninth septum..	35 mm.	
Lateral diameter at ninth septum.....	30 mm.	
Length of body chamber.....	38 mm.	47 mm.
Dorso-ventral diameter of aperture.....	37 mm.	43 mm.
Lateral diameter of aperture.....	22 mm.	37 (?, broken)
Average spacing of septa.....	4.5 mm.[1]	6 mm.

As no shell is preserved, the character of the surface cannot be ascertained. The casts show a row of bead-like markings along the posterior margin of the chamber of habitation; this feature, however, is not uncommon in casts of other species of the genus.

The first two septa posterior to the chamber of habitation are more closely set than is indicated in the figures given above: this is particularly well marked in the larger of the two specimens. The remaining septa are fairly evenly spaced. The forward arching of the septa is very slight. The siphuncle is small and marginal in position.

Whiteaves describes three species of *Poterioceras* from the Galena-Trenton and Black River formations of Lake Winnipeg[2]—*P. nobile, P. apertum, and P. gracile:* the first of these species is much larger than our specimens and contracts much more rapidly towards the aperture; the second species is a less elongate form. With almost the same dorso-ventral diameter as our smaller specimen the height of the body chamber is only 31 mm. and the shell tapers more rapidly posteriorly. *P. gracile* could not possibly be mistaken for the present form, as it is extremely elongate with a chamber of habitation 115 mm. long and only 35 mm. wide.

Named for the collector, J. B. Tyrrell, Esq., of Toronto, chief of the Hudson Bay Exploring Expedition of 1912.

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 320 S. Royal Ontario Museum of Palaeontology.

---

[1] Through a printer's error or otherwise, this measurement is given as 3.5 mm. in the original preliminary description.

[2] Trans. Royal Soc., Can., Vol. VII, sect. IV, pp. 77 and 78, pl. XIV, figs. 204; pl. XV, fig. 1, 1889; *Ibid.*, Vol. IX, sect. IV, pp. 87-88, pl. XI, figs. 2 and 3; pl. XII, figs. 4 and 4a, 1891. Also Geol. Sur. Can., Palaeoz, Foss., Vol. III, pt. III, pp. 216-220.

DISCOCERAS (?) SHAMATTAWENSE, *sp. nov.*

Plate I, Figure 1.

TROCHOCERAS INSIGNE, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 192.

The specimen consists of a well preserved mould of part of the exterior showing portions of four volutions. The whorls appear to be wound in a plane and to come in contact with each other without an impressed zone. The volutions increase very gradually in width and are ornamented with bold costæ, most strongly developed on the inner side, passing almost directly outward and becoming fainter with an orad inflection near the outer margin of the whorl. The mould gives the impression that the venter was rather narrow. The outer volution is not quite complete, but is probably 22 mm. wide; the second volution has a width of 12 mm. and the third a width of 7 mm. The costæ on the outer whorl are 5.5 mm. apart on the median line; on the second whorl they are 4 mm. apart and on the third whorl 2 mm. apart.

Having no knowledge of the later stages of growth, of the aperture, or of the siphuncle it is impossible to give this form a definite generic position. The manner of coiling, however, strongly suggests the genus *Discoceras* to which the species is provisionally ascribed.

In the preliminary report, I identified this specimen with *Trochoceras insigne*, Whiteaves, but a closer examination has induced me to alter my opinion. The original description of *T. insigne* (Ottawa Naturalist, Vol. XII, p. 124) carries the statement that the whorls are "closely contiguous", but the figure in Plate XLI, Vol. III of Palaeozoic Fossils, shows a shell with a gyroceran mode of coiling, not presented by our species. The costæ in Whiteaves' species are more widely spaced and turn apicad on the exterior margin, whereas in our species they are inflected slightly orad.

The specimen bears some resemblance to *Lituites bickmoreanus*, Whitfield, but that species is more closely costated and the costæ are directed apicad as they approach the venter. Further, the whorls expand much more rapidly in *L. bickmoreanus*.

A stronger resemblance is presented by *Goniatites*? *solitarius*, Barrande, as figured on Plate 464, Système Silurien de la Bohême; in fact the only difference seems to be a slightly more direct course in the costae of our species. Barrande's specimen was obtained from Etage G, g1, at Hlubocep, which is too high for our specimen.

Locality—Lower rapids, Shamattawa river, Manitoba.
Horizon—Ordovician.

No. 325 S. Royal Ontario Museum of Palaeontology.

ASCOCERAS BOREALE, *Parks*.

Plate II, Figures 8 and 9.

ASCOCERAS BOREALE, *Parks*, Bur. of Mines of Ont., 22nd Rep., pt. I, p. 192, 1913.

The species is represented in the collection by one fairly well preserved specimen, showing the general shape and the septal markings. The anterior prolongation or neck of the body chamber is broken off and the apex is slightly worn.

The general form is sub-ovate and rather acuminate towards the apex when viewed from the dorsal or ventral aspects. Viewed from the lateral aspect the pointed apex is not observed, the outline being almost elliptical if the anterior prolongation of the chamber of habitation be disregarded. The greatest width is in advance of the mid-length and is 34 mm. dorso-ventrally and 55 mm. laterally, indicating a shell with considerable dorso-ventral flattening. The length from the anterior sigmoidal saddle to the apex is 46 mm., to which probably 2 mm. more should be added on account of the abrasion of the apex.

A vertical section shows portions of two cameræ, the anterior of which is 1.5 mm. and the posterior slightly less. Cameræ further apicad are lost. The sigmoidal saddles are not preserved in the interior.

The suture of the coalesced septa crosses the venter as a slight lobe: it then turns dorsal and orad until the two sides are within 12 mm. of each other on the dorsal side. A sharp inflection ventral and orad then occurs, with the septa still coalesced for a distance of 17 mm. Beyond this point four distinct dorsal saddles are indicated, showing intervals on the dorsum of 7 mm., 6 mm., and 3 mm. respectively from posterior to anterior.

This species is of the general type of *Ascoceras bohemicum*, Barrande,[1] and it closely resembles *A. costulatum* described by Whiteaves from the Galena-Trenton of Black island, Lake Winnipeg.[2] Whiteaves' form is larger, however, and is more rounded at the apex. The sutures of the sigmoidal saddles also appear to have a different course, as Whiteaves' figure shows two sutures approximately parallel as viewed from the ventral side, whereas such an appearance would be impossible in our form.

Ascoceras canadense, Billings[3] is a comparable type, but our form is much less ventricose dorso-ventrally and the sutures of the sigmoidal saddles are united much more forward. *A. anticostiense* and *A. newberryi* of Billings are not at all comparable.

---

[1] Systeme Silurian de la Boheme, pls. 93, 94 and 96.

[2] Geol. Sur. Can., Palaeox. Foss., Vol. III, p. 215, pl. XXII, fig. 1.

[3] Geol. Sur. Can., Rep. for 1853-56, p. 310; *Ibid.*, for 1863, p. 218 with figure.

Whiteaves (*op. cit.*) states: "*A. costulatum* would seem to be nearest to *A. canadense*, Billings, the type of Hyatt's genus *Billingsites*, and hence may be referable to that genus". This remark would apply with equal force to *A. boreale*.

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 326 S. Royal Ontario Museum of Palaeontology.

TRILOBITA.

BUMASTUS, *sp. indet.*

One specimen embedded in matrix showing the interior of the thorax and a small portion of the pygidium; also a specimen showing a cast of the pygidium with three thoracic rings attached. No portion of a buckler is preserved.

The thorax of the larger specimen is fully 45 mm. wide with ten rings 4 to 5 mm. in width. The axis is about 35 mm. wide, but the axal furrows are faintly shown and the pleura are broken off. The pygidium is rounded and smooth with no evidence of trilobation.

This specimen evidently belongs to the genus *Bumastus*, and it resembles in a general way *B. trentonensis*, Emmons, which Ulrich considers to be identical with *Illænus milleri*, Billings. The present form is, however, much larger and is possibly distinct. In the preliminary report these specimens were referred to *Illænus americanus*, Billings: the axis is too broad and the axal furrows too ill defined to confirm this identification.

Locality—Lower rapids, Shamattawa river, Manitoba.

Horizon—Ordovician.

No. 424 S. Royal Ontario Museum of Palaeontology.

II

ORDOVICIAN SPECIES FROM THE DRIFT

The following species were collected from the superficial deposits chiefly from near the mouth of the Shamattawa river. Most of the specimens represent a fauna similar to that at the lower rapids, but one specimen seems to indicate a higher horizon comparable with the Cincinnatian.

Cf. RAFINESQUINA ALTERNATA, *Emmons* sp.

STROPHOMENA ALTERNATA, *Emmons*, Geol. Sur., N.Y., Rep. 2nd Dist., p. 395, fig. 3, 1842.

One cast of the convex valve resembling this species, but impossible of certain identification.

Locality—Drift, mouth of the Nelson river, Manitoba.
Horizon—Ordovician probably.
No. 406 S. Royal Ontario Museum of Palaeontology.

WHITELLA, *sp. indet.*

Plate IV, Figure 15.

One imperfect cast of the interior of a left valve. The shell is about 43 mm. long and possibly 28 to 30 mm. high, but the ventral margin is not preserved. In the drawing this margin has been restored in a dotted line. The beaks are very prominent and incurved. The umbonal ridges are well developed and there is a defined depression dorsal to the beak extending forward, possibly to the extreme anterior margin of the shell. All these characteristics are typical of *Whitella*, and I have little doubt that the specimen belongs in this genus: it is too imperfect to justify a specific description.

Locality—Mouth of Shamattawa river, Manitoba (Drift).
Horizon—Ordovician.
No. 423 S. Royal Ontario Museum of Palaeontology.

ISOTELUS, *sp. indet.*

One fragment of a large species of *Isotelus*. The eight thoracic rings show a length of about 60 mm. Small portions of the buckler and of the pygidium are preserved, but all distinctive characteristics are obliterated. This specimen is probably referable to *I. gigas*, De Kay.

Locality—Drift at Limestone rapids, Severn river, District of Patricia.
Horizon—Ordovician.
No. 425 S. Royal Ontario Museum of Palaeontology.

One fragment from a boulder at the mouth of the Shamattawa river consists of a fine grained, argillaceous limestone of light brownish colour. The substance of the included shells has entirely disappeared, but moulds are preserved of some organisms which have been so flattened that exact determination is impossible. The most abundant species is a large Gastropod, 30 to 35 mm. in diameter, referable with reasonable certainty to *Liospira*. Species probably belonging to *Cymatonota* or *Orthodesma* occur, and *Byssonychia* or a closely allied genus is represented by one impression. The specimen also shows the impression of a *Cyrtoceras*. These fossils indicate a Cincinnatian rather than a Mohawkian horizon. (No. 950 H.R. Royal Ontario Museum of Palaeontology.)

III

SILURIAN SPECIES

The greater number of the following species was obtained at the Limestone rapids of the Severn river, the Limestone rapids of the Fawn river or the Assina rapids of the Severn river. The fauna indicates a horizon comparable with the Guelph and shows many species common to the region of the Attawapiskat and Ekwan rivers.

ACTINOZOA

AMPLEXUS SEVERNENSIS, *Parks* sp.

Plate III, Figure 12.

TYRRELLIA SEVERNENSIS, *Parks*. Bur. Mines of Ont., 22nd Rep., p. 193, 1913.

This very beautiful and well preserved little coral is represented by three specimens in a single piece of stone from Limestone rapids on the Severn river.

The corallites are single, circular, gently expanding to a known length of 18 mm. and a width of 6 mm. Surface and calyx unknown.

The tabulæ are complete, flat or slightly arched in the centre, but turned down abruptly between the septa near the periphery. The spacing of the tabulæ is fairly regular, with an average distance apart of .5 mm. In some cases they are a little more closely set.

The septa number about 50 at the maximum diameter. The primaries reach the full length of the corallite near the periphery, but they are interrupted on the under sides of the tabulæ towards the centre and consequently appear as vertical plates on the upper sides of the tabulae and do not extend to the tabula next above save at the periphery of the corallite. In the younger stages the septa are relatively much longer than in the later life of the coral. Near the apex they are in contact with each other on the upper centres of the tabulæ, and extend on the under surface of the tabula next above for about two-thirds of the diameter, thus leaving a V-shaped opening between the inner ends of the opposite septa. Near the top of the corallum, the septa are relatively very much shorter and apparently fail to extend, even on the upper surface of the tabulae, more than a third of the way to the centre. The secondary septa are very short and appear only as longitudinal ridges between the primaries. No other endothecal structures are present.

The development of the septa in this species suggests an intermediate position between *Zaphrentis* and *Amplexus*: on this account I decided in the preliminary report to erect a new genus, *Tyrellia*, for its reception. Further consideration, however, has induced me to place the form under *Amplexus*. According to the definition of the two genera given by Milne-Edwards and Haime, our specimen is a *Zaphrentis* when young and an *Amplexus* when old, because in the younger stages the septa meet at the centre of the tabulæ and in older stages they "do not extend to the centre of the visceral chamber and leave the upper surface of the tabulæ naked and smooth in that part". It was on this account that I proposed to create a new genus. Lambe, however, defines *Amplexus* as differing from *Zaphrentis* "only in the feeble development of the septa". There is no difficulty in placing the form under *Amplexus* in view of this more generalized definition. I am also inclined to this decision by a comparison of our form with the figure of *Amplexus coralloides*, Sowerby, which appears in Plate XXXVI of Milne-Edwards and Haime's monograph of the British Fossil Corals.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.

No. 300 S. Royal Ontario Museum of Palaeontology.

Cf. CYSTIPHYLLUM NIAGARENSE, *Hall* sp.

CONOPHYLLUM NIAGARENSE, *Hall*. Pal., N.Y., Vol. II, p. 114, pl. 32, figs. 4a-n, 1852.
CYSTIPHYLLUM HURONENSE, *Billings*. Cat. Sil. Foss., Anticosti, p. 92, 1866.
CYSTIPHYLLUM NIAGARENSE, *Rominger*. Geol. Sur. Mich., Foss. Corals, p. 137, pl. XLIX, fig. 3, 1876.
CYSTIPHYLLUM NIAGARENSE, *Sherzer*. Bull. Geol. Soc. Am., Vol. III, p. 266, 1892.
CYSTIPHYLLUM NIAGARENSE, *Lambe*. Ottawa Nat., Vol. XII, p. 224, 1899.
CYSTIPHYLLUM NIAGARENSE, *Lambe*. Geol. Sur. Can., Cont. to Can. Palaeon., Vol. IV, pt. II, p. 190, pl. XVI, fig. 7, 1900.

The collection contains one small fragment showing the endothecal tissue and part of the calyx of a form evidently referable to *Cystiphyllum*. The calyx appears to have been fairly deep, and it shows traces of septa on the blistery surface. General shape and size of the corallum not determinable. Very doubtfully referred to *C. niagarense* on account of the depth of the calyx.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.

No. 340 S. Royal Ontario Museum of Palaeontology.

HALYSITES CATENULARIA, *Linnaeus.*

Plate V, Figure 6.

TUBIPORA CATENULARIA, *Linnaeus.* Syst. Nat., ed. 12, p. 1270, 1767.
HALYSITES CATENULARIA, *Milne-Edwards and Haime.* British Fossil Corals, p. 270, pl. LXIV, figs. 1, 1a, 1b, 1c, 1850. (See this work extended synonomy.)
HALYSITES CATENULARIA, *Lambe.* Geol. Sur. Can., Cont. to Can. Palaeon., Vol. IV, pt. I, p. 68, pl. III, figs. 1, 1a, 1b, 2, 2a, 3, 3a, 1899.
HALYSITES CATENULATUS, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. I, p. 196, 1913.

This rather common Silurian coral is represented by two specimens from the Limestone rapids of the Severn and Fawn rivers. It is possible that a variety might be founded on the specimen from the Severn river, as it possesses remarkably wide connecting tubes between the corallites proper: these smaller tubes are filled with numerous, arched, overlapping, closely set, delicate tabulæ. The variety resembles *H. catenularia nitida*, Lambe (*op. cit.*) but it differs in the great irregularity of the tabulæ in the small tubes.

Locality—Limestone rapids, Severn river; Limestone rapids, Fawn river, District of Patricia, Ontario.

Horizon—Silurian.

Nos. 337 and 338 S. Royal Ontario Museum of Palaeontology.

PYCNOSTYLUS, *Whiteaves.*

PYCNOSTYLUS, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. I, p. 2, 1884.

Dr. Whiteaves' original description of this genus is as follows: "Internal structure very similar to that of *Amplexus*, the radiating septa being rudimentary and extending but a short distance from the inner surface of the outer wall, but the tabulæ, though well developed and complete, are entirely horizontal, and neither bend upwards at the periphery nor embrace each other with their reflexed margins. Corallum compound, consisting apparently of an aggregation of numerous, slender, cylindrical or sub-cylindrical polyp stems, which divide by calicular gemmation at distant intervals into sets of three, four or more ascending, sub-parallel, contiguous, flexuous branches. Structure of the calices previous to gemmation, and character of the basal portion of the corallum unknown".

Whiteaves describes two species, *P. guelphensis* and *P. elegans*: in the former the corallites are from 3 to 7 mm. in diameter and the epitheca is marked by transverse constrictions but is without longitudinal septal furrows. In the latter species the corallites are from 13 to 17 mm. in diameter and the outer surface is regularly and longitudinally ribbed.

The following statement is significant: "It is possible that the specimens for which the above name (*P. elegans*) is provisionally suggested may prove to be portions of the basal extremity of *P. guelphensis* denuded of their epitheca, but at present no intermediate examples between the two forms have been collected".

Our collection contains twelve specimens in an indifferent state of preservation, none of which show any features other than those of the ordinary portions of the corallites, *i.e.*, there is no evidence of the bifurcations, point of attachment or calyx. The average size of the corallites varies greatly, but they may be arranged in five groups as follows:

Diameter of corallites, average	5 mm.—Two specimens.
" " " "	7 mm.—One specimen.
" " " "	9 mm.—Two specimens.
" " " "	16 mm.—Five specimens.
" " " "	25 mm.—Two specimens.

In all the specimens the actual substance of the corallite—epitheca, septa, and tabulæ seems to be of extreme tenuity, and the preservation in each case is due to secondary deposits of calcite. Specific differentiation on the basis of mere size is very hazardous, and lacking epithecal characteristics we are deprived of the second means of identification. On the whole, however, it seems advisable, provisionally at least, to ascribe the 5 and 7 mm. types to *P. guelphensis*; the 9 and 16 mm. types to *P. elgans*, and to make a new species for the 25 mm. type.

PYCNOSTYLUS GUELPHENSIS, *Whiteaves.*

AMPLEXUS LAXATUS, *Billings.* Geol. Sur. Can., Rep. 1863, pp. 340 and 342, 1863.
AMPLEXUS? SP., *Nicholson.* Palaeontology of Ontario, p. 66, 1875.
PYCNOSTYLUS GUELPHENSIS, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. 1, p. 3, pl. I, figs. 1, 1a and 1b, 1884.
PYCNOSTYLUS GUELPHENSIS, *Whiteaves. Ibid.*, pt. II, p. 49, 1895.
PYCNOSTYLUS GUELPHENSIS, *Lambe.* Geol. Sur. Can. Cont. to Can. Pal., Vol. IV, pt. 2, p. 132, pl. X, figs. 4 and 4a, 1900.
PYCNOSTYLUS GUELPHENSIS, *Parks.* Bur. Mines of Ont., 22nd Rep., p. 193, 1913.

Three specimens containing in all about 40 corallites which vary in diameter from less than 5 to slightly more than 7 mm. The tabulæ are rather more widely spaced than in the type, for our specimens seldom show more than 4 tabulæ in a centimetre, whereas Whiteaves recognizes from 5 to 9 in his types. The absence of longitudinal ribs on the exterior, a characteristic of *P. guelphensis*, is clearly indicated by at least one of the corallites.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 301 S. Royal Ontario Museum of Palaeontology.

PYCNOSTYLUS ELEGANS, *Whiteaves.*

Plate I, Figure 3.

PYCNOSTYLUS ELEGANS, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. I, p. 4, pl. I, figs. 2, 2a, 1884.
PYCNOSTYLUS ELEGANS, *Whiteaves. Ibid.*, pt. II, p. 49, 1895.
PYCNOSTYLUS ELEGANS, *Lambe.* Geol. Sur. Can., Cont. to Can. Pal., Vol. IV, pt. II, p. 133, 1900.
PYCNOSTYLUS ELEGANS, *Lambe.* Cruise of the Neptune, p. 326, 1906.
PYCNOSTYLUS ELEGANS, *Parks.* Bur. Mines of Ont., 22nd Rep., p. 193, 1913.

The specimens ascribed to this species vary from 9 mm. to more than 16 mm. in diameter. Most of the specimens are embedded in matrix and show only the internal characters. One specimen, probably decorticated, shows longitudinal ribbing and transverse striations. Another small specimen has the epitheca excellently preserved: its structure tends to confirm the identification and to strengthen Whiteaves' conclusions as to the specific difference of *P. elegans.* This epitheca (Pl. I, Fig. 3) shows delicate and fairly even transverse ridges, which are more crowded in some parts than in others. Vertical ridges or ribs are also well marked, and correspond in position with the very short septa. In the finer specimens (9 mm. diam.) the tabulæ are about 3 mm. apart, for the most part flat, but slightly arched in places. This smaller form might, with equal reason, be ascribed to *P. guelphensis.* The larger specimens show much variation in the spacing of the tabulæ: generally they are from 3 to 4 mm. apart, but in one instance an interval as great as 14 mm. separates them. In view of the extreme delicacy of the original tabulæ, and the consequent opportunities for destruction, too much reliance must not be placed on this feature. In this specimen also, the tabulæ are arched and slightly crenulated at the margins. There is also some indication of two orders of septa, which is a feature not admitted by Whiteaves in his description of the type.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.

No. 302 S. Royal Ontario Museum of Palaeontology.

PYCNOSTYLUS MAXIMUS, *sp. nov.*

Plate I, Figure 2.

This species is represented by two small fragments only, but they are sufficiently different from the known species to justify their reference to a new type.

The corallites attained a diameter of at least 25 mm. and probably exceeded that size in some cases. Although the specimens are very

short, there is evidence of a more rapid tapering than is shown by the other species. The septa, epitheca and tabulæ are all extremely delicate. Whether these structures were strengthened during the life of the organisms by deposits of stereoplasma, or whether the present condition of the specimens is due entirely to subsequent deposition of calcite, I cannot with certainty assert, but I am strongly inclined to the latter view.

The decorticated exterior (Pl. I, Fig. 2) shows vertical furrows 3·5 mm. apart at a diameter of 25 mm. In the second fragment, which evidently belongs to a larger specimen, these depressions are fully 4 mm apart. Between these major furrows, is another scarcely less pronounced. A third order of furrows, somewhat less distinct, occurs between those of the first and second orders. Delicate transverse growth lines are also to be seen.

The major set of furrows corresponds in position with the primary septa, which in the larger specimen extend inwards 3 or 4 mm. At a diameter of 25 mm. about 22 primary septa occur. The secondary furrows probably represent the position of secondary septa, but only the slightest indication of these can be seen. The third order of furrows probably represents a third order of septa, but no evidence of their extension inwards is to be observed.

The tabulæ are complete, horizontal, and about 8 mm. apart. In the centre they are quite flat, but at the periphery they are sharply inflected downwards between the primary septa: this gives the line of junction between the tabulæ and the epitheca a crenulated appearance. The secondary septa produce an extremely slight upward inflection of this downward fold but the tertiary septa, if present, have no effect on the crenulation. Viewed from above, a tabula shows ridges marking the position of the primary septa and extending inwards a distance of 7 mm.

There can be no doubt that this form is close to the genus *Amplexus:* the downward inflection of the tabulæ and the continuation of the septa as ridges on the upper side of the tabulæ point strongly to that genus. On the other hand the general resemblance to *Pycnostylus elegans* is pronounced, especially in view of the fact that some crenulation of the margins of the tabulæ was observed in certain examples of that species (See page 40). If absolutely no crenulation of the tabular margins is permissible in *Pycnostylus* then the present form must be transferred to *Amplexus*.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 303 S. Royal Ontario Museum of Palaeontology.

FAVOSITES HISINGERI, *Milne-Edwards and Haime.*

FAVOSITES HISINGERI, *Milne-Edwards and Haime.* Polyp. Foss. des Terr. Palaeoz., p. 240, pl. XVII, figs. 2, 2a and 2b, 1851.
FAVOSITES HISINGERI, *Lambe.* Geol. Sur. Can., Cont. to Can. Pal., Vol. IV, pt. 1, p. 6, 1899. (For extended synonomy see this work.)
FAVOSITES HISINGERI, *Parks.* Bur. Mines of Ont., 22nd Rep., p. 182, 1913.

One broken specimen indicating a hemispheric corallum about 70 mm. in diameter. The corallites are about 1.5 mm. in diameter. The mural pores are relatively large and are arranged in one or two rows on the sides of the corallites. The tabulæ are flat and vary from 2 to 3 or even 4 in one mm. The long spiniform septa, characteristic of the species, are not as well shown as the other features, but in certain parts of the corallum they are distinctly discernible. Other similar specimens.

Locality—Limestone rapids and Assina rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

Nos. 304 S. and 343 S. Royal Ontario Museum of Palaeontology.

Cf. FAVOSITES GOTHLANDICA, *Lamarck.*

FAVOSITES GOTHLANDICA, *Lamarck.* Hist. des An. sans Vert., Vol. II, p. 206, 1816.
FAVOSITES GOTHLANDICA, *Lambe.* Geol. Sur. Can., Cont. to Can. Pal., Vol. IV, pt. 1, p. 3, pl. I, fig. 1, 1899. (See this work for extended synonomy.)

Two specimens from different localities are provisionally ascribed to this species, but specific determination of Favositoid corals demands much better material than that in hand.

One specimen from the Limestone rapids, Severn river, is evidently part of a large corallum. The corallites are extremely variable in size, closely appressed, polygonal, reaching a diameter of over five mm. The tabulæ are flat or slightly wavy and closely set; they average somewhat more than a millimetre in spacing. No septa, septal spines, or mural pores are to be seen. Without these latter features, specific differentiation is of course impossible, but as *F. gothlandica* has been reported from the region it is a reasonable assumption that our form belongs to that species, although the tabulæ are more closely set than is usual in specimens with corallites of the present size.

The second specimen is from the Limestone rapids of the Fawn river: it shows corallites of about 3 mm. maximum diameter. The tabulæ are regularly arranged at a distance of 1 mm. from each other.

No septa, septal spines or pores are observable, even on polished surfaces.

Locality—Limestone rapids, Severn river; Limestone rapids, Fawn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 306 S. (Severn river), No. 307 S. (Fawn river) Royal Ontario Museum of Palaeontology.

PETRAIA (?), *sp. indet.*

A single badly crushed specimen presenting the following features: Corallum, straight, conical, 45 mm. long; width at top 27 by 14 mm., representing a probable diameter of about 20 mm. External surface shows transverse growth lines and well marked septal furrows. Septa probably about 65 in number.

A vertical section shows nothing but crushed and broken septa which suggests the genus *Petraia*. Although the specimen is greatly flattened the preservation is sufficiently good to justify the conclusion that other internal structures are absent. This conclusion is strengthened by the fact that the outer wall is little broken, although the specimen is crushed flat; this would indicate a lack of supporting structures in the interior.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 298 S. Royal Ontario Museum of Palaeontology.

STREPTELASMA *cf.* ROBUSTUM, *Whiteaves.*

STREPTELASMA CORNICULUM (?) *Hall.* Large and robust variety. *Whiteaves*, Geol. Sur. Can., Rep. Prog. for 1879-80, p. 57c. 1881.

STREPTELASMA ROBUSTUM, *Whiteaves.* Can. Rec. Sci., Vol. VI, p. 391, 1896.

STREPTELASMA ROBUSTUM, *Whiteaves.* Pal. Foss., Vol. III, pt. III, p. 153, pl. XVIII, figs. 1, 1a, 1897.

STREPTELASMA ROBUSTUM, *Lambe.* Geol. Sur. Can., Cont. Can. Pal., Vol. IV, pt. II, p. 109, 1900.

The specimen is very imperfect, but it indicates a *Streptelasma* of considerable size. The fragment is about 80 mm. long: it shows a strong curvature and a rapid expansion in diameter. At the top the diameter of the corallum is about 40 mm. The exterior is not shown, and the calyx is entirely broken away. A cross section shows about 70 primary septa, which reach close, if not quite to the centre. Secondary septa are absent or very slightly developed. Very numerous, close-set and inwardly arched dissepiments are seen in the interseptal loculi. A vertical section shows the strong development of dissepiments, which

are about .5 to 1 mm. apart. On the concave side of the corallum they turn upwards in a sigmoidal curve, at first convex upwardly and later concave. These elements seem to form a central spongy zone with the inner edges of the septa. On the convex side of the corallum the course of the dissepiments is shorter, but owing to mineralisation the structure is not well revealed.

The form is evidently a large species of *Streptelasma*, but its specific determination is impossible on account of the fragmentary nature of the specimen: it much resembles the figure given by Whiteaves for *S. robustum* on Plate XVII, Vol. III, Palaeozoic Fossils, but the absence of secondary septa makes the transverse section very different from that figured by Lambe for *S. robustum* on Plate VII, Vol. IV, Cont. to Can. Pal.

Streptelasma robustum is an Ordovician species, whereas the associations of the present example are Silurian. It is unlikely that we are dealing with a strictly co-specific type, but the condition of the specimen does not justify more than a comparison.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.

No. 289 S. Royal Ontario Museum of Palaeontology.

Cf. ZAPHRENTIS STOKESI, *Milne-Edwards and Haime.*

ZAPHRENTIS STOKESI, *Milne-Edwards and Haime.* Polyp. Foss. des Terr. Palaeoz., p. 330, pl. 3, fig. 9, 1851.
?CANINIA BILATERALIS, *Hall.* Pal. N.Y., Vol. II, p. 41, pl. 17, fig. 3, and p. 113, pl. 32, fig. 3, 1852.
?POLYDILASMA TURBINATUM, *Hall.* Ibid. p. 112, pl. 32, fig. 2, 1852.
ZAPHRENTIS STOKESI, *Billings.* Cat. Sil. Foss. Anticosti, p. 34, 1866.
ZAPHRENTIS STOKESI, *Nicholson.* Pal. of Ont., pp. 43 and 58, 1875.
ZAPHRENTIS STOKESI, *Rominger.* Geol. Sur. Mich., Foss. Corals, p. 144, pl. LI, three figures in lower row, 1876.
ZAPHRENTIS STOKESI, *Lambe.* Geol. Sur. Can., Cont. Can. Pal., Vol. IV, pt. 21, p. 120, pl. IX, figs. 1, 1a and 2, 1900.

It is with considerable doubt that the specimens in hand are referred to this species: some of them are badly broken, while others, apparently in good condition, are so filled with secondary thickenings that the nature of the internal structures is not clearly revealed.

All the specimens show an intermediate stage between the typical structure of *Streptelasma* and that of *Zaphrentis*. The central reticulate area of *Streptelasma* is not seen, but on the other hand the continuous tabulæ of *Zaphrentis* are but ill defined.

One small and fairly well preserved specimen presents the following features: Corallum turbinate, 35 mm. long in a straight line; maxi-

mum diameter 22 mm.; tetrameral symmetry clearly shown in the septal furrows on the exterior; at a diameter of 16 mm. there are about 45 primary septa showing well marked tetrameral symmetry and presenting very nearly the appearance of Plate IX, Figure 2 of Lambe's work. The long primary septa reach the middle, and although much thickened appear to be somewhat twisted together. The secondary septa are very poorly developed and can scarcely be observed in the stereoplasma connecting the peripheral ends of the primaries. The vertical section, owing to secondary thickening, is very poor and only faintly reveals the presence of irregular tabulæ.

Another specimen is somewhat larger than the above, and shows the same pronounced tetrameral structure. The inner ends of the septa are much curved, particularly the shorter ones, which seem in some cases to unite. Towards the periphery of the corallite, the interseptal elements more resemble upwardly directed dissepiments, but towards the centre of the coral they cannot be described as other than tabulæ, although they are very curved and incomplete.

None of the specimens afford any evidence of the character of the calyx. It is apparent that the form only distantly resembles *Z. stokesi*: the secondary septa are too short and the tabulae are too badly defined, nevertheless I am of the opinion that our specimens approach more closely to this species than to any other described form: it seems advisable, in the absence of better material, to ascribe the specimens provisionally to *Z. stokesi*.

Locality—Assina rapids and vicinity, Severn river, District of Patricia, Ont.

Horizon—Silurian.

Nos. 292 and 293 S. Royal Ontario Museum of Palaeontology.

INCERTAE SEDIS

A fragment of limestone contains several broken corallites of the general aspect of *Pycnostylus* or *Amplexus*. The apparent internal diameter of the tubes is about 2 mm., while the external diameter varies up to 7 mm. This outer annulus consists of solid carbonate of lime quite structureless: it is impossible to say whether it is part of the corallite or whether it represents secondary calcite deposition. The tube is crossed by distinct, flat, tabulæ at intervals of 1.5 mm. Some of the corallites show short but distinct septa, while others are without these structures.

If we assume that the thick outer wall is due to secondary deposition the form may be ascribed to *Pycnostylus*, but to a species considerably finer in structure than *P. guelphensis*. It is possible that the

thick outer annulus represents a zone of vesicular tissue in which the structure has been destroyed by mineralisation: in this case, the habit of growth would suggest *Diphyphyllum*. The size of the corallites suggests *Aphyllostylus gracilis*, Whiteaves,[1] but it is difficult to ascribe it to that species in the absence of the characteristic spines. It is quite possible, however, that in certain of the corallites these spines have been destroyed and that in one instance they have been so united by depositions of calcite as to resemble continuous septa.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 305 S. Royal Ontario Museum of Palaeontology.

One fragment of limestone from the Limestone rapids of the Severn river contains the casts and moulds of an unusual type of coral, possibly referable to *Pycnostylus*.

The largest example is 25 mm. long, circular in cross section and about 20 mm. in diameter at the anterior end. For about 17 mm. there is little diminution in diameter, but below that point the decrease in diameter is greater and there is some evidence of curving.

The only structures actually preserved are an exceedingly delicate epitheca, very short and delicate septa and possibly a few tabulæ at the posterior end of the specimen.

The epitheca is of extreme tenuity, marked vertically by septal furrows which are but little more than a millimetre apart, and raised into rows of blunt protuberances in the interseptal tracts. The external appearance is therefore very different from that of any coral with which I am familiar. A small portion magnified five times is shown in Plate I, Figure 4.

The septa are so delicate and short that their extension inward cannot be observed.

Towards the base of the specimen there is evidence of complete, upwardly arched, irregularly developed tabulæ. No other endothecal structures are to be seen. Unless more anterior tabulæ have been destroyed, the form must have possessed a calyx of extraordinary depth.

I have little doubt that these specimens represent a Rugose coral which should be ascribed to a new genus: the material, however, is much too imperfect to justify the erection of a genus at present.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 339 S. Royal Ontario Museum of Palaeontology.

[1] Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 278, pl. XXIV, figs. 1 and 1a, 1906.

STROMATOPOROIDEA

STROMATOPORA CONSTELLATA, *Hall.*

STROMATOPORA CONSTELLATA, *Hall.* Pal. N. York, Vol. II, p. 324, pl. LXXII, figs. 2a and b, 1851.
STROMATOPORA CONCENTRICA, *Hall.* Pal., N. York, Vol. II, pl. LXXIII, figs. 2, 2a and 2b, 1851.
COENOSTOMA CONSTELLATUM, *Spencer.* Bull. Univ. State of Miss., Vol. I, no. I, p. 48, pl. VI, fig. 11, 1882.
STROMATOPORA CONSTELLATA, *Whiteaves.* Can. Rec. Sci., Vol. VII, p. 137, 1896.
STROMATOPORA HUDSONICA, *Dawson.* Quart. Jour. Geol. Soc., Vol. XXXV, p. 52, pl. IV, figs. 9a and 9b; pl. V, fig. 10, 1879.
STROMATOPORA HUDSONICA, *Nicholson.* Mon. Brit. Strom., Pal. Soc., p. 172, 1891.
STROMATOPORA HUDSONICA, *Nicholson.* Ann. and Mag. Nat. Hist., p. 312, pl. VIII, figs. 1-3, 1891.
STROMATOPORA CONSTELLATA, *Parks.* Ottawa Nat., Vol. XXII, p. 28, 1908.
STROMATOPORA CONSTELLATA, *Parks.* Univ. of Toronto Studies, Geol. Ser., No. 5, p. 44, pl. XIII, figs. 7, 8 and 9, 1908.

Several specimens indifferently preserved, but one of which shows the astrorhizæ in an excellent manner.[1] Some of these examples were erroneously referred to *Actinostroma tenuifilatum* in the preliminary report.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.

No. 410 S. Royal Ontario Museum of Palaeontology.

CLATHRODICTYON CYSTOSUM, *Rominger* sp.

STROMATOPORA VESICULOSA, *Rominger.* Proc. Acad. Nat. Sci. Phil., p. 50, 1886.
STROMATOPORA CYSTOSA, *Rominger.* MSS. United States National Museum labels.
CLATHRODICTYON CYSTOSUM, *Parks.* Univ. of Toronto Studies, Geol. Series, No. 5, p. 21, pl. VII, figs. 2, 3 and 4; pl. VIII, figs. 6 and 8, 1908.
CLATHRODICTYON CYSTOSUM, *Parks.* Univ. of Toronto Studies, Geol. Series, No. 6, p. 29, 1909.

This species is represented by a fragment from a large cœnosteum in which the structure is very well preserved. Sections indicate a close resemblance to the type of *C. cystosum*, but they also show some points of difference. The chief variation is seen in the vertical arrangement of the cysts in some parts of the cœnosteum whereby the vertical elements appear more pronounced than the horizontal; this effect is

[1] In the works above mentioned I have recorded the occurrence of the following species of Stromatoporoids in the Silurian of the Hudson Bay region: *Clathrodictyon vesiculosum*, *C. drummondense*, *C. fastigiatum*, *C. cystosum*, *C. cystosum lineatum*, *C. cystosum cylindricum*, *C. striatellum*, *C. vesiculosum minutum*, *Actinostroma tenuifilatum*, *A. tenuifilatum inflectum*, *A. franklinense*, *A. tenuifilatum cylindricum*, *Stromatopora constellata*, *S. wilsoni*, *S. carteri*, *S. amii*, *S. indianensis*, *Actinodictyon neptuni*, *A. keelei*, and *A. lowi*.

well seen on weathered surfaces. It is quite possible that this variation is of specific value, but having examined numerous examples of the species, I am of the opinion that too much attention to variation would result in the creation of a species for almost every specimen.

Locality—Assina rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 409 S. Royal Ontario Museum of Palaeontology.

BRYOZOA

FENESTELLA SUBARCTICA, *Whiteaves.*

FENESTELLA SUBARCTICA, *Whiteaves.* Geol. Sur. Can., Ann. Rep., Vol. XIV, pt. F, p. 39, 1904.
FENESTELLA SUBARCTICA, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 249, pl. 23, 1906.
FENESTELLA SUBARCTICA, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 192, 1913.

One small specimen showing the reverse side.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 418 S. Royal Ontario Museum of Palaeontology.

BRACHIOPODA

PLECTAMBONITES TRANSVERSALIS. *Wahlenberg* sp.

ANONITES TRANSVERSALIS, *Wahlenberg.* Act. Soc. Upsaliensis, Vol. III, p. 64, n. 4, 1821.
LEPTAENA TRANSVERSALIS, *Dalman.* Vet. Acad. Handl, p. 109, pl. I, fig. 4, 1828.
LEPTAENA TRANSVERSALIS, *Hisinger.* Pet. Suecica, p. 69, pl. 20, fig. 5, 1837.
LEPTAENA TRANSVERSALIS, *Murchison.* Sil. Syst., p. 629, pl. 13, fig. 2, 1839.
STROPHOMENA TRANSVERSALIS, *Hall.* Geol. Rep., N. York, p. 105, fig. 4, 1843.
LEPTAENA TRANSVERSALIS, *Hall.* Pal., N. York, Vol. II, p. 256, pl. LIII, figs. 5a-1, 1851.
PLECTAMBONITES TRANSVERSALIS, *Hall and Clarke.* Pal., N. York, Vol. VIII, pt. I, p. 298, pl. XV, figs. 34-36, 1892.

One cast with a part of the shell adhering. The dorsal valve is very convex and the ventral valve deeply concave. The cardinal angles are broken off. The shell shows numerous distinct striæ, with very delicate intermediate striae. Although the specimen is very imperfect the identification is made with some assurance.

Locality—Limestone rapids, Fawn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 407 S. Royal Ontario Museum of Palaeontology.

ATRYPA, *sp. indet.*

Two decorticated ventral valves presenting the general shape of *Atrypa.* The ornamentation consists of very fine radiating striæ only.

Locality—Limestone rapids, Fawn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 408 S. Royal Ontario Museum of Palaeontology.

STROPHEODONTA, *sp. indet.*

Plate IV, Figure 17.

One imperfect pedicle valve. About 25 mm. wide and 17 mm. high. Moderately convex. Cardinal line extended beyond the general width of the shell. Surface marked with very fine striæ and an occasional stronger one.

Locality—Limestone rapids, Fawn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 413 S. Royal Ontario Museum of Palaeontology.

STROPHEODONTA, *sp. indet.*

Plate IV, Figure 18.

One imperfect pedicle valve. Cardinal angles broken, but the shell was probably 35 mm. wide and 22 to 25 mm. high. Valve strongly convex. Surface lost, but indications remain of fairly coarse striæ—much coarser than in the species described above. This form is possibly *Strophomena donnettii* mentioned by Salter as occurring on Griffith's island. (Journal of a Voyage, etc., App. p. ccxxiv, pl. 5, figs. 11 and 12.)

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 414 S. Royal Ontario Museum of Palaeontology.

GLASSIA VARIABILIS, *Whiteaves.*

GLASSIA VARIABILIS, *Whiteaves.* Geol. Sur. Can., Ann. Rep., Vol. XIV, pt. F, p. 42, 1904.
GLASSIA VARIABILIS, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, 273 and 277, pl. 26, figs. 3, 4, 5, 7, 8, 9, 1906.
GLASSIA VARIABILIS, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. I, p. 192, 1913.

This species appears to be abundant, and is represented by thirteen specimens resembling the types of the species rather than the variety figured by Whiteaves in figures 7, 8 and 9 *op. cit.*

Locality—Above Limestone rapids, Severn river, District of Patricia.
Horizon—Silurian.
No. 385 S. Royal Ontario Museum of Palaeontology.

CAMAROTOECHIA EKWANENSIS, *Whiteaves.*

CAMAROTOECHIA EKWANENSIS, *Whiteaves.* Geol. Sur. Can., Ann. Rep., Vol. XIV, pt. F, p. 42, 1904.
CAMAROTOECHIA EKWANENSIS, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 252, pl. 25, figs. 4, 4a and 4b, 1906.
CAMAROTOECHIA EKWANENSIS, *Parks.* Bur. Mines of Ont., 2nd Rep., pt. I, p. 192, 1913.

One specimen is an internal cast, somewhat less gibbous but otherwise resembling Whiteaves' species.

Locality—Limestone rapids, Severn river, District of Patricia.
Horizon—Silurian.
No. 386 S. Royal Ontario Museum of Palaeontology.

GLASSIA VARIABILIS, *Whiteaves*, var.

Plate III, Figure 11.

One pedicle valve and one cast of the same. The specimen closely resembles the variety of *G. variabilis* described by Whiteaves from the Ekwan river in Volume III of Palaeozoic Fossils, page 252, Plate 26, Figures 6, 6a and 6b. Our specimen is larger and somewhat more elongate. Lacking any knowledge of the interior, I was at first inclined to ascribe the species to *Barrandella*, as it is distinctly more elongate, much more ventricose, and with a more prominent beak on the pedicle valve than the type of *Glassia variabilis*.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 400 S. Royal Ontario Museum of Palaeontology.

TRIMERELLA EKWANENSIS, *Whiteaves*.

TRIMERELLA EQUANENSIS, *Whiteaves*. Ottawa Naturalist, Vol. XVI, p. 141, pl. 2, figs. 1 and 2; pl. 3, fig. 1, 1902.
TRIMERELLA EKWANENSIS, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 249, pl. 24, fig. 7; pl. 25, figs. 1 and 2, 1906.
TRIMERELLA EKWANENSIS, *Parks*. Bur. Mines of Ont., 22nd Rep., pt. 1, p. 192, 1913.

A single broken specimen of an internal cast, which, coming from this locality, may reasonably be referred to Whiteaves' species, although the definite specific characteristics can scarcely be made out.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 387 S. Royal Ontario Museum of Palaeontology.

RHYNCHOSPIRA LOWI, *Whiteaves*.

RHYNCHOSPIRA LOWI, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 277, pl. 25, figs. 8 and 9, 1906.

One mould of the pedicle valve with part of the decorticated shell adhering. Apparently belongs to this species.

Locality—Limestone rapids, Fawn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 388 S. Royal Ontario Museum of Palaeontology.

A more imperfect fragment of the brachial valve from the Limestone rapids of the Severn river is provisionally placed here.

No. 389 S. Royal Ontario Museum of Palaeontology.

PENTAMERUS OBLONGUS, *Sowerby*.

PENTAMERUS LAEVIS, *James Sowerby*. Min. Con., Vol. I, p. 76, pl. 28, 1813.
PENTAMERUS OBLONGUS, *J. de C. Sowerby*. Silur. Syst., pl. 19, fig. 10, 1839.
PENTAMERUS OBLONGUS, *Hall*. Geol. Rep. 4th Dist., N. York, p. 7, figs. 1-5, 1843.
PENTAMERUS OBLONGUS, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. II, p. 63, 1895. (See this article for extended synonomy.)

This well known species is represented by a single example which I am unable to differentiate from Sowerby's species. The form resembles almost exactly the example figured by Whitfield in Figure 4, Plate 17, Wisconsin Geological Survey, Volume IV.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 390 S. Royal Ontario Museum of Palaeontology.

CONCHIDIUM *cf.* DECUSSATUM, *Whiteaves* sp.

PENTAMERUS DECUSSATUS, *Whiteaves*. Can. Rec. of Sci., Vol. IV, 295, pl. 3, figs. 3 and 4, 1891.
CONCHIDIUM DECUSSATUM, *Hall and Clarke*. Pal. N. York, Vol. VIII, pt. 2, p. 235, pl. 65, figs. 1 and 2; pl. 66, fig. 15, 1894.
CONCHIDIUM DECUSSATUM, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 293, pl. 26, figs. 1 and 2, 1906.

The collection contains three fragments which are provisionally referred to this species. One fragment from the drift at the mouth of the Nelson river (No. 391 S) shows part of a brachial valve very closely resembling Whiteaves' figures. A second specimen from the same locality (No. 392 S) is an internal cast of a pedicle valve which resembles the type figures in a less satisfactory manner, as the strongly arched outline of the shell is not apparent in our specimen. A third specimen (No. 393 S), also from the Nelson river, is so deformed by pressure that its identity with the others is conjectural only. The fourth specimen (No. 394 S) is a cast of a brachial valve indicating a shell flatter than No. 391 S and apparently more finely striate. I very much doubt the identity of this fragment with the others.

Conchidium decussatum was described by Whiteaves from material obtained at the Grand Rapids of the Saskatchewan river, and it is not recorded by him in the lists of specimens from the Ekwan and Attawapiskat rivers.

In referring all the present examples to this species, I am exceeding their proved identity, but the material is much too imperfect to warrant description, and it seems better, provisionally, to place them all under this species.

Locality—Drift, mouth of Nelson river, District of Patricia.
Horizon—Probably Silurian.
Nos. 391 to 394 S. Royal Ontario Museum of Palaeontology.

BARRANDELLA (?) MESOPLICATA, *sp. nov.*

Plate III, Figures 8, 9 and 10.

Three imperfect casts of a small shell having a length of 11 mm. and a width of rather less than 10 mm., also another specimen probably of the same species but with a greater proportional width.

Both valves are prominently convex, with a beak of the larger valve incurved; it is probable that the shell would show scarcely any interval between the beaks. The umbonal region is smooth in both valves, but towards the anterior margin a broad sinus is developed in the larger valve marked in the centre by a rather sharp rib. Outside the more prominent ribs bordering the sinus are single, short, and faintly defined ribs. The corresponding crenulations on the smaller valve are rather less prominent. The greatest width of the shell is anterior to the mid-length and the outline of the larger valve is sub-trigonal. This valve is rather flat in the mid region, but the smaller valve is sharply convex with slight concavities towards the lateral margins.

With no knowledge of the interior, it is manifestly impossible to ascribe this species to its proper genus. The external appearance suggests a Merestelloid, Camarelloid, or Pentameroid shell. I am inclined to provisionally place the species under the latter type in the genus *Barrandella*. The form is remarkably like *Sieberella nucleus*, Hall and Whitfield, but in *Sieberella* the sinus is on the brachial valve. On this interpretation the larger valve is of course the pedicle. The specimens also suggest the genus *Parastrophia*, but they are probably too elongate for that genus. If the interior should reveal a Camarelloid structure the species should probably be removed to *Parastrophia*, in which case the larger valve is the brachial.

Locality—Assina rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 399 S. Royal Ontario Museum of Palaeontology.

SPIRIFER CRISPUS, *Hisinger* sp.

TEREBRATULA CRISPA, *Hisinger*. Act. R. Acad. Sci. Holmiensis, tab. VII, fig. 4, 1826.
TEREBRATULA CRISPA, *Hisinger*. Idem. Anteckn. IV, tab. VII, Fig. 4.
DELTHYRIS CRISPUS, *Dalman*. Vet. Acad. Handl., p. 122, tab. 3, fig. 6, 1827.
DELTHYRIS CRISPUS, *Hisinger*. Petref. Suecica, p. 73, t. XXI, fig. 5a and 5b, 1839.
SPIRIFER CRISPUS, *Sowerby*. Murichson's Sil. Syst., p. 624, pl. 12, fig. 8, 1839.
DELTHYRIS STAMINEA, *Hall*. Geol. Rep. 4th Dist., N. York, p. 105, fig. 3, and p. 106, 1843.
SPIRIFER CRISPUS, *Hall*. Pal., N. York, Vol. II, p. 262, pl. LIV, figs. 3a-k, 1851.
SPIRIFER CRISPUS (?), *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 253, pl. 27, fig. 1, 1906.

This common species occurs in the Niagara of America as well as in corresponding Silurian strata of Europe. It is also recorded in the Guelph and is referred to by many authors. The occurrence in the present association is rather to be expected, but we have only one specimen partly buried in matrix. Whiteaves (*op. cit.*) describes and figures a small form from the Ekwan river in which the ribs are narrow and angular instead of broad and rounded; our specimen is nearer the type than the variety figured by Whiteaves.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 395 S. Royal Ontario Museum of Palaeontology.

DELTHYRIS, *sp. indet.*

Plate III, Figure 13.

DELTHYRIS *cf.* SULCATUS, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 195, 1913.

A single cast of one valve partially imbedded in matrix. The general appearance suggests *Delthyris sulcatus*, Hisinger *sp.*, but the mesial fold is not developed. The shell is about 15 mm. wide and seven or possibly eight mm. in height; it is marked by three prominent rounded ribs in the median region and by three similar but smaller ribs towards the angles. The specimen is much too imperfect to warrant a specific name; provisionally it may be regarded as related to *Delthyris sulcatus*. It is on the basis of this resemblance only that the species is referred to *Delthyris*.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 397 S. Royal Ontario Museum of Palaeontology.

MERISTINA (?) EXPANSA, *Whiteaves.*

MERISTINA (?) EXPANSA, *Whiteaves.* Geol. Sur. Can., Ann. Rep., Vol. XIV, pt. F., p. 45, 1904.

MERISTINA (?) EXPANSA, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 245, pl. 27, figs. 6, 6a and 7, 1906.

The collection contains three specimens of small size (about 20 mm. in diameter) which conform closely with Whiteaves' description. The shell is preserved, but the outer layer has exfoliated partially, but not enough to expose the concentric ornamentation figured by Whiteaves. The most perfect shell has a practically smooth exterior, and seems to indicate a perforation in the beak of the pedicle valve.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 398 S. Royal Ontario Museum of Palaeontology.

PELECYPODA

MODIOMORPHA (?) ACUMINATA, *Parks*.

Plate IV, Figures 12, 13 and 14.

MODIOMORPHA ACUMINATA, *Parks*. Bur. Mines of Ont., 22nd Rep., pt. I, p. 194, 1913.

This species is represented by nine specimens more or less complete. Some variation is shown in the general shape of the different examples, but this may be due partly to age; it is quite possible, however, that more than one species is represented.

The best preserved specimen is about 70 mm. long. The anterior end is very narrow and acuminate. The greatest height is well towards the posterior (about 35 mm.). The umbo is almost if not quite at the anterior end, and the hinge line is slightly arcuate. The surface is ornamented by lines of growth only; these are more pronounced at intervals. There is a very slight depression in the sides of the valves giving a sinuate ventral margin. The left valve of this shell is shown in Figure 12 and a cast of the right valve in Figure 13. This cast shows a simple pallial line, a large anterior adductor scar and evidence of a fairly wide and heavy hinge plate. Unfortunately the posterior scar is not shown, nor is the detail of the hinge preserved. The figure, therefore, is not to be regarded as a restoration, but as showing only what is revealed in the specimen. A second cast shows some evidence of a large posterior scar in the dorsal region. This cast also shows evidence of the continuation of the hinge plate posteriorly and a peculiar wrinkling of the median portion of the shell which does not appear on the exterior. The specimen figured as No. 14 is the interior of the left valve of a smaller shell which shows the hinge very well, but in which the tip of the beak is broken off as well as the posterior margin. The edge of the actual specimen is shown in the figure with the probable correct outline dotted. The ventral part of the shell is filled with matrix and does not show the pallial line. Other examples present an anterior outline even more acuminate than the one figured, and these shells show scarcely any lateral depression. Despite the variations, I am inclined to include all the specimens in one species and to refer them to the genus *Modiomorpha*. This genus is Devonian, but its essential features are presented by one or other of our specimens; it has a heavier hinge plate than typical examples of *Modiolopsis*, it possesses a fairly strong tooth over the muscular scar in the left valve and, in the type specimen at least, presents a slight depression in the lateral aspect with a consequent sinuosity of the ventral margin. It is freely admitted that more than one species may be represented, but the features revealed present common generic characteristics suggesting *Modiomorpha*; in view of this genus being

Devonian, and as all the characters are not presented by any one shell, I have made the reference to this genus provisional only.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 419 S. Royal Ontario Museum of Palaeontology.

SILURINA (?), *sp. indet.*

Plate V, figure 9.

The collection contains one extremely poor cast of the left valve of an ovate Pelecypod measuring 65 mm. by about 50 mm. The valves are rather flat, with the greatest thickness above and in front of the mid-point. The total thickness of a cast would not exceed 24 mm. There is no evidence of the beak or of the hinge line. The antero-ventral margin is distinctly crenulated as if the shell gaped a little at that point.

I have been unable to find any American Silurian shell with which this specimen is comparable except possibly *Ilionia* (*Prælucina*). Barrande figures a number of shells, mostly from his Etage e2, under the generic name *Silurina*. Some examples of *Silurina distorta*, particularly that figured as No. 23, Plate 42, Vol. VI, Systême Silurien de la Bohême, approaches closer to our specimen than any other species I have been able to find. It is unfortunate that the specimen is so imperfect as to render its identification uncertain, but I cannot do better than to refer it provisionally to *Silurina*.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 429 S. Royal Ontario Museum of Palaeontology.

GASTROPODA

BELLEROPHON, *sp. indet.*

Plate IV, Figure 5.

A single imperfect cast of the interior. The general form of the shell is globular, but it is somewhat extended towards the aperture, which appears to be but little expanded. No evidence is presented of the existence of a slit band or transverse markings, but towards the aperture the dorsum becomes much more acuminate than in the major portion of the shell. The whorls are closely wound and overlapping, leaving a small umbilicus. The inner lip was strengthened by a strong callosity which appears in the cast as a deep circular pit surrounding the stony matter filling the umbilicus. The outer side of this cavity

shows a distinct furrow, which must represent a considerable revolving ridge projecting inwards from the inner side of the whorl. This form shows considerable resemblance to *Bellerophon nautarum*, Salter.[1]

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 356 S. Royal Ontario Museum of Palaeontology.

BELLEROPHON (CYMBULARIA), *sp. indet.*

Plate IV, Figures 6 and 7.

This species is represented by four fragmentary specimens, all casts of the interior, of which none show the characters of the aperture. Even the generic relations are therefore doubtful, but the general shape of the casts suggests *Bellerophon* as redefined by Ulrich. The forms resemble very closely some of the species referred to *Cymbularia* of Koken.

The forms are closely convolute with about three whorls and a very small umbilicus. The whorls expand rather rapidly to the aperture, which does not seem to be greatly enlarged. The dorsum is marked by a distinct but slightly elevated band, which increases in prominence towards the aperture. Transverse lines of growth cross the dorsum almost at right angles.

The specimens are all so fragmentary that a specific name would not be justified; the closest resemblance is presented by *Cymbularia rotunda*, Barrande *sp.* Systême Silurien de la Bohême, Vol. IV, p. 154, Pl. 86, Figs. 14-17.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 355 S. Royal Ontario Museum of Palaeontology.

MEGALOMPHALA ROBUSTA, *Whiteaves.*

MEGALOMPHALA ROBUSTA, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, p. 257, pl. XXVIII, figs. 9 and 9a, pl. XXIX, fig. 1, 1906.
MEGALOMPHALA ROBUSTA, *Parks.* Bur. Mines, Ont., 22nd Rep., pt. 1, p. 194, 1913.

The species is represented by a single broken cast of the interior, but I have little doubt as to the correctness of the identification.

Locality—Limestone rapids, Severn river, District of Patricia.
Horizon—Silurian.
No. 353 S. Royal Ontario Museum of Palaeontology.

[1] Sutherland, Journal of a Voyage, etc., app., p. ccxxiii, pl. 5, fig. 25.

HORMOTOMA *cf.* WHITEAVESI, *Clarke and Ruedemann.*

LOXONEMA MAGNUM, (*Whitfield*), *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. 1, p. 17, 1884; *Idem.*, pt. II, p. 87, pl. 13, fig. 2, 1895.
HORMOTOMA WHITEAVESI, *Clarke and Ruedemann.* New York State Mus., Memoir 5, p. 72, pl. 8, figs. 5-9, 1903.
HORMOTOMA WHITEAVESI, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, p. 332, 1906.

Three casts of the interior remarkably like this species. Lacking any evidence of the external markings, etc., the forms are provisionally placed under *H. whiteavesi.*

The largest of the specimens shows a body whorl of about 30 mm. in diameter with a height of 20 mm. which is identical with the figures of Clarke and Ruedemann. Except for the smaller size the present specimens are very like *H. patriciaensis*, herein described. In fact they may possibly be the apical parts of the same species, but the apical angle is greater in *H. patriciaensis*, which inclines me to keep the species separate.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 364 S. Royal Ontario Museum of Palaeontology.

HORMOTOMA PATRICIAENSIS, *Parks.*

Plate I, Figure 8.

HORMOTOMA PATRICIAENSE, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. I, p. 194, 1913.

This species is founded on a single cast of the interior showing three whorls, but the collection contains another specimen indicating nearly the same proportions. The type specimen is 100 mm. long with a body whorl about 50 mm. in diameter. The apical angle is 25 degrees. The outline of the whorls is gently convex from suture to suture, and shows no evidence of revolving band or ornamentation of any kind. Lacking the lip structures and any portion of the shell, the generic relations are impossible to determine, but the general aspect of the cast suggests *Hormotoma* or possibly *Fusispira.*

This form bears some resemblance to *Hormotoma winnipegensis*, Whiteaves,[1] in the general shape of the whorls, but it differs greatly in the relative height and width of the whorls. For a given height of whorl our species has a width of only two-thirds that of Whiteaves' species; it is undoubtedly close to *Loxonema magna*, Whitfield,[2] but that species

[1] Geol. Sur. Can., Palaeoz. Foss., Vol. III, p. 192, pl. XXI, fig. 1.
[2] Wisconsin Geol. Sur., Vol. IV, p. 317, pl. 24, fig. 1.

appears to have a smaller apical angle and the height of a given whorl to its width is 28 to 38, whereas the relation in our species is 28 to about 50.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 345 S. Royal Ontario Museum of Palaeontology.

Cf. COELIDIUM MACROSPIRA, *Hall* sp.

MURCHISONIA MACROSPIRA, *Hall.* Pal., New York, Vol. II, p. 346, pl. 83, fig. 5, 1852.
COELIDIUM MACROSPIRA, *Clarke and Ruedemann.* New York State Museum, Memoir 5, p. 65, pl. 7, figs. 2-8; pl. 10, fig. 13, 1903.
COELOCAULUS MACROSPIRA, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 333, 1906. (See this work for further synonomy.)

One fragmentary cast which is so near to this species that it may be provisionally referred to it.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 365 S. Royal Ontario Museum of Palaeontology.

Cf. COELIDIUM BIVITTATA, *Hall* sp.

MURCHISONIA BIVITTATA, *Hall.* Pal., N. York, Vol. II, p. 345, pl. 83, figs. 1a and 1b, 1852.
COELOCAULUS BIVITTATUS, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 334, 1916. (See this work for further synonomy.)

One fragmentary cast of the interior closely resembling this species in the shape and proportions of the whorls and in the nature of the spire. The characteristic structure of the species is doubtfully indicated in the interior; but lacking better material, our specimen may reasonably be referred to *C. bivittata.* Following Clarke and Ruedemann I have ascribed the species to *Coelidium* rather than to *Coelocaulus.*

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 366 S. Royal Ontario Museum of Palaeontology.

COELIDIUM, *sp. indet.*

Plate I, Figure 6.

CLATHROSPIRA *sp.*, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. I, p. 194, 1913.

This species is represented by one broken cast of the interior showing the body whorl in a fairly complete manner and portions of the succeeding two whorls. The figure is largely restored and is therefore open to objections, particularly with regard to the whorls represented by dots.

The body whorl has a width of 45 mm. and it is relatively large compared with the whorls of the spire. A slightly elevated band can be

made out on the periphery a little below the mid height. Above the band the outline is convex to the suture, and the same type of outline is observed below the band but with a rather steeper slant. The whorls decrease rapidly in size and the spire presents an apical angle of about 65 degrees. The aperture is probably fairly elongate, but there is no evidence as to the character of the lip.

It is manifestly impossible to ascribe such an imperfect specimen to its proper genus, but I have no doubt as to its specific distinctness.

In the original description (*op. cit.*) this form was placed under *Clathrospira* on account of its resemblance to *C. deiopeia*, Billings sp.[1] A more detailed examination and the construction of the restored figure shows that the apical angle is rather too small and the whorls of the spire not sufficiently depressed for the genera *Clathrospira* and *Eotomaria*.[2] In the general shape of the shell the present species is very like *Murchisonia vitellia*, Billings,[3] but it differs in the absence of a concavity in the outline of the whorl above the revolving band. *Murchisonia vitellia* is considered to be a *Coelidium* by Clarke and Ruedemann[4] while Whiteaves held the opinion that it might be ascribed to *Lophospira*.[5] Our specimen shows no evidence of the degree of angularity which is seemingly required for the genus *Lophospira*, and in consequence it is provisionally placed under *Coelidium*. The genus *Plethospira* of Ulrich[6] is in many respects very close to the present species. Except for the larger apical angle of our species it might be compared with *Murchisonia chamberlini*, Whitfield.[7]

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 346 S. Royal Ontario Museum of Palaeontology.

EOTOMARIA *cf.* GALTENSIS, *Billings* sp.

PLEUROTOMARIA GALTENSIS, *Billings*. Geol. Sur. Can., Palaeoz. Foss., Vol. I, p. 154, fig. 136; *Ibid.*, Rep. 1863, p. 334, fig. 349.
PLEUROTOMARIA GALTENSIS, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. II, p. 75, pl. 11, fig. 7, 1895.
EOTOMARIA GALTENSIS, *Clarke and Ruedemann*. N.Y. State Museum, Mem. 5, p. 70, pl. 10, figs. 10-12, 1903.
EOTOMARIA GALTENSIS, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 332, 1906.

---

[1] Geol. Sur. Can., Palaeoz. Foss., Vol. III, p. 75, pl. XII, fig. 1.
[2] Geol. and Nat. Hist. Sur., Minn., Palaeontol., Vol. III, pt. II, p. 954.
[3] Geol. Sur. Can., Palaeoz. Foss., Vol. I, p. 156, fig. 138, p. 155.
[4] New York State Museum, Memoir 5, p. 67, pl. 7, figs. 9 and 10.
[5] Geol. Sur. Can., Palaeoz. Foss., Vol. III, p. 333.
[6] Geol. and Nat. Hist. Sur., Minn., Vol. III, pt. II, p. 1008, fig. 7, p. 1009.
[7] Geol. Sur., Wis., Vol. IV, p. 317, pl. 24, fig. 4.

A species of *Eotomaria* is represented by a single cast of the interior embedded in matrix. Two whorls are exposed; the maximum width of the first is 12.5 mm. and that of the second is 7 mm. The apical angle is the same as that of *E. galtensis*. The whorls show a sharp edge at the inferior periphery and a gently convex upper surface with a slight concavity just above the margin. The width of the upper surface from the sharp edge of the lower whorl to the suture is 7 mm. The under side of the whorl is convex but is rather less pronounced in this respect than *E. galtensis*. The under side of the whorl seems to increase in convexity towards the aperture, and as our specimen has lost a considerable portion of the body whorl, it is likely that the resemblance of a more perfect specimen to *E. galtensis* would be even more pronounced.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 357 S. Royal Ontario Museum of Palaeontology.

EOTOMARIA (?) HOPKINSI, *sp. nov.*

Plate I, Figure 5.

EOTOMARIA *sp.*, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 194, 1913.

This little species is represented by a single cast showing only parts of two whorls; its general shape and its resemblance to *Eotomaria durhamensis*, Whiteaves, induces me to ascribe it to that genus. In the preliminary report (*op. cit.*) I compared it directly with *E. durhamensis*, but on making a drawing I find that it differs considerably in the apical angle and that it apparently has a more elongated aperture.

The width of the body whorl is 15 mm. and its height 13 mm. The second whorl is very much smaller, with a width of only 8 mm. A distinct revolving ridge occurs about midway on the whorls, making a sharp angulation. Above the ridge the outline of the whorl is rather flat, but with a very slight concavity followed by a slight convexity to the suture. Beneath the band, the outline is rounded with only the slightest evidence of a concavity near the ridge. The outline of the body whorl below the band varies greatly as the aperture is approached, becoming much steeper in that direction. A more extended knowledge of this species might result in its transference to *Lophospira*: the general shape suggests a type like *Murchisonia mylitta*, Billings, which is now regarded as a *Lophospira*. Named for P. E. Hopkins, who was Mr. Tyrrell's assistant on the exploration of the Severn river.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 362 S. Royal Ontario Museum of Palaeontology.

EUOMPHALUS ROTUNDUS, *sp. nov.*

Plate VII, Figures 6 and 7.

This species is represented by two imperfect specimens, one showing a mould of the base and portions of the internal casts of the lower whorls and the other showing a mould of the apical side with parts of the shell adhering to the matrix. In addition are several fragments, probably referable to this species.

The maximum diameter of the larger shell is about 85 mm. The coiling is discoidal with three volutions. The umbilicus is wide open and about 18 mm. deep. On the apical side, the central point is depressed 7 mm. below the line joining the upper surfaces of the opposite sides of the body whorl. In Plate VII, Figure 7, this depression does not appear as great, but this is owing to the absence of the shell, which is much thicker (3 mm.) on the body whorl than on the small whorls near the centre. The whorls are almost circular in the cast, having a lateral diameter of 24 mm. and a vertical diameter of 23 mm. at a point convenient for measurement. The apical portion of the whorls is filled with a white, organically deposited calcite arranged in convex diaphragms simulating the septa of a cephalopod. Neither of the shells show the slightest evidence of the surface characteristics, and there is no trace of a peripheral alation; in fact, the shape of the whorl is a reasonable basis for the assumption that such structures were not present. Some of the smaller pieces indicate that at least the inner sides of the whorls were marked by fine transverse lines of growth. Accepting Lindström's description of *Euomphalus* there can be no doubt that our species falls within that genus.[1]

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
Nos. 348 and 349 S. Royal Ontario Museum of Palaeontology.

EUOMPHALUS MINOR, *sp. nov.*

Plate IV, Figures 8 and 9.

TREPOSPIRA *cf.* KOKENI, *Lindström, Parks.* Bur. Mines of Ont., 22nd Rep., pt. I, p. 194, 1913.

This species is represented by a fragmentary mould of the exterior and by an internal cast which apparently belongs to the same species. The shell is about 8 mm. wide with a low depressed spire. Four whorls in all can be made out indistinctly.

The mould shows a relatively large body whorl characterised by a gently rounded lateral aspect with a rather sharp carina in the superior

[1] Sil. Gast. and Pter. of Gotland, p. 136.

external position. Between the carina and the suture there is a distinct concavity followed by a gentle convexity. The whorls of the spire are largely hidden by the lower whorls, and the exposed portion shows only a gentle convexity with slight if any evidence of the carina.

The cast shows, in a much less distinct manner, the features given above. Near the aperture the carina and the superior concavity are visible, but about half way around the body whorl these features are obscured and the upper surface is flat, sloping gently upwards to the suture. The whorls of the spire are rounded and show no trace of angulation.

The generic position of a shell in which aperture, umbilicus and slitband are not observable must of necessity be doubtful. The outline of the body whorl suggests the genus *Helicotoma*, but the failure of the carina on the whorls of the spire is a departure from this genus. The form of the shell is also remarkably like that of *Euomphalus præcursor*, Lindström[1]; in fact the only differences are the more marginal position of the elevated ridge and its *apparent* failure on the whorls of the spire. Ulrich regards *E. præcursor* as marking a stage in the development of *Ophileta* into the typical *Euomphalidae*. It would appear, therefore, that our species represents either a degenerate type of *Helicotoma* extending into the Silurian, or a species of primitive *Euomphalus* allied to *E. præcursor*. On the whole the latter conclusion is probably better justified, but our material is much too imperfect to warrant definite statements as to generic position.

In the preliminary report this species was referred provisionally to *Trepospira kokeni*, Lindström sp. A more detailed study has induced me to alter my opinion as above.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 396 S. Royal Ontario Museum of Palaeontology.

EUOMPHALUS, *sp. indet.*

Plate VII, Figure 10.

A single cast of the interior of a discoidally wound shell about 43 mm. in diameter. Three whorls are shown. The section of a whorl shows a generally rounded outline with a superior flattening and a peripheral angulation above the mid-height. The umbilicus is wide open and 11 mm. deep. The upper surface was probably very nearly flat or possibly slightly elevated.

There can be little doubt that this form belongs to *Euomphalus*, but the specimen is too poorly preserved to warrant a specific name. The

[1] Sil. Gast. and Pter. of Gotland, p. 140, pl. XVIII, figs. 9-11.

species can be easily differentiated from a young example of *E. rotundus* by the shape of the whorl and the lack of an apical depression.

Locality—Above Limestone rapids, Severn river, District of Patricia.

Horizon—Silurian.

No. 369 S. Royal Ontario Museum of Palaeontology.

EUOMPHALOPTERUS TYRRELLI, *Parks*.

Plate III, Figures 15 and 16.

EUOMPHALOPTERUS TYRRELLI, *Parks*. Bur. of Mines of Ontario, 22nd Rep., pt. 1, p. 194, 1913.

This species is founded on a single fragmentary cast showing the interior of part of the body whorl and part of the alar expansion or carina of the first whorl of the spire. The extraordinary size of the specimen has induced me to attempt a restoration of the shell which is shown in Plate III, Figure 15. While this figure shows correctly the size and general shape of the shell, it is to be understood that the whole of the ornamentation has been restored from the markings disclosed on the mould of the alar expansion of the first whorl of the spire. The direction of the lines of growth on the alation and on the outer aspect of the volutions is correct, but the direction on the upper side of the volution was not disclosed in the specimen, and has been restored without any supporting evidence.

The cast indicates an actual width for the interior of the shell of 200 mm.; adding to this the extent of the alation the total diameter was at least 295 mm. and may have been greater, as there is no evidence in the specimen that the whole of the body whorl is preserved. The cast of the first volution at its maximum point shows a width of 51 mm. and a height of 36 mm. It is evenly rounded on the interior and rather flat on the upper surface to within about 20 mm. of the outer margin. At this point it falls off rapidly to a sharp edge almost at the base of the whorl. The under side shows a slight concavity within the outer margin and then a rather stronger convexity which fades into the evenly rounded interior aspect. The spire is gently ascending, as the base of the cast of the second volution is about on a level with the upper surface of the first volution, and is separated from it by an interval of 18 mm. Although nothing is known of the inner whorls, this method of coiling would indicate only three or four whorls in all.

A fragment about 100 mm. long shows the impression of the alation of the second whorl which bridges over the interval between the internal casts of the two whorls and reaches about half way across the upper flat surface of the outer whorl. The actual width of the alation at this

point is 57 mm. This fragment shows the lines of growth on the carina to curve gently forward, while on the outer aspect of the whorl they are inclined backwards. Unfortunately the direction of these lines on the upper side of the whorl is not revealed. The outer aspect of the whorl, besides the lines of growth, carries seven revolving striæ.

In my original description (*op. cit.*) it is stated that the whorls are seven in number; a more detailed examination and a reconstruction indicate that they probably did not exceed four.

Besides the lines of growth the impression of the alation shows delicate, close-set lines running forward and outward; I interpret these marks as due to the presence of tubuli in the alation, and I have indicated their direction on the lower portion of the figure. These markings would not be visible on the exterior of the shell.

The generic position of this remarkably fine shell is of course somewhat doubtful, as the character of the aperture is not revealed. The low-set and wide alation with tubuli arching forward and outward as well as the general shape of the whorl correspond with *Euomphalopterus* as defined by Ulrich, but the open character of the coils proper and their restricted number seem to be departures from the generic type.

I am informed by Mr. Tyrrell that he observed numerous examples of this gigantic gastropod along the Severn river. It seems fitting that this, the most remarkable fossil of the collection, should bear Mr. Tyrrell's name.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 344 S. Royal Ontario Museum of Palaeontology.

EUOMPHALOPTERUS *cf.* VALERIA, *Billings* sp.

PLEUROTOMARIA VALERIA, *Billings*. Geol. Sur. Can., Palaeoz. Foss., Vol. I, p. 169, 1865.
PLEUROTOMARIA VALERIA, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, p. 23, pl. 4, figs. 1 and 1a, 1884; *Ibid.*, p. 71, pl. XI, figs. 2, 3.
EUOMPHALOPTERUS VALERIA, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, p. 339.
EUOMPHALOPTERUS VALERIA, *Parks*. Bur. Mines of Ont., 22nd Rep., pt. I, p. 196, 1913.

This species is represented by a single, well preserved cast of the interior. The specimen is about 53 mm. in maximum diameter, and agrees so closely with Whiteaves' figure that it must be ascribed to *Euomphalopterus valeria*, although the determination of species from internal casts is necessarily hazardous. It should be noted (*op. cit.*) that Whiteaves considers that *E. valeria* is probably the same as *E. alatus*, Wahlenberg. A second specimen from the same locality is

probably a mould of the umbilical side of the same species; it shows lines of growth and evidence of an alar expansion.

Locality—Assina rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 352 S. Royal Ontario Museum of Palaeontology.

PYCNOMPHALUS COLEMANI, *sp. nov*,

Plate I, Figures 9 and 10. Plate VII, Figure 3.

This species is represented by a single imperfect specimen from which the upper part of the spire has been removed by erosion; it is nevertheless sufficiently preserved to justify the creation of a new species.

The specimen is about 85 mm. in diameter and shows an excellent cast of the base (Plate I, Fig. 10). The upper side is very imperfect and shows only the outer whorl and a trace of the margin of the second whorl; it will be understood, therefore, that Plate I, Figure 9 is largely restored. The casts of the whorls are of oval shape with a ratio of 5 to 3 in the lateral and vertical diameters.

A vertical section shows sufficient of the shell to indicate clearly the reference of the species to *Pycnomphalus*. The long and upwardly curved callosities are indicated in dotted lines on Plate VII, Figure 3. The upper callosity on the left and the one on the right of the figure are actually preserved; the lower one on the left is restored. The inner ring shown on Plate I, Figure 10 rests on the upper side of the basal callosity.

This species differs so distinctly from *P. salaroides*, Whiteaves, or from any of the species figured by Lindström from Gotland that no comparative remarks are required. Named for Dr. A. P. Coleman, Professor of Geology, University of Toronto.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 347 S. Royal Ontario Museum of Palaeontology.

PYCNOMPHALUS, *sp. indet.*

Plate VII, Figure 9.

This species is represented by one water-worn fragment, which is so ill preserved that nothing of the external characters is shown. A vertical section, however, shows that the shell is about 45 mm. in diameter, that the spire is but slightly elevated, that the volutions are rather sharply angulated at the periphery, rounded below, and slightly impressed above by the next whorl. The basal whorl bears a distinct

callosity which shows some evidence of being hollow, as it is bounded by shelly matter and filled with crystalline calcite; it is more likely, however, that the calcite has partially replaced the substance of the callosity. The second whorl shows a distinct thickening of the shell on the inner side, but a pronounced callosity as in the basal whorl is not observed. The specimen is much too imperfect for specific determination, but it appears to belong to the genus *Pycnomphalus*, and undoubtedly represents an undescribed species.

Locality—Assina rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 368 S. Royal Ontario Museum of Palaeontology.

GYRONEMA DOWLINGII, *Whiteaves.*

GYRONEMA DOWLINGII, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 259, pl. 29, fig. 3, 1906.
GYRONEMA DOWLINGII, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 193, 1913.

The species is represented by one broken cast which is sufficiently distinct to leave little doubt of the identification, and by several fragments of smaller individuals.

Locality—Above Limestone rapids, Severn river, District of Patricia.
Horizon—Silurian.
No. 354 S. Royal Ontario Museum of Palaeontology.

Cf. GYRONEMA SPECIOSUM, *Whiteaves.*

GYRONEMA SPECIOSUM, *Whiteaves.* Geol. Sur. Can., Ann. Rep., Vol. XIV, pt. F, p. 50, 1904.
GYRONEMA SPECIOSUM, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 258, pl. 29, fig. 2, 1906.
GYRONEMA SPECIOSUM, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 193, 1913.

One fragment of a body whorl probably referable to this species. The ornamentation of the under side of the whorl is like that of *G. speciosum*, but near the periphery the revolving ridges are distinctly wider spaced. The ornamentation of the upper side is not preserved. The specimen may represent a variety of *G. speciosum*, but it is much too imperfect for description.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 370 S. Royal Ontario Museum of Palaeontology.

A second specimen of very small size shows only a portion of one whorl, but it presents the ornamentation of *G. speciosum* in a manner which admits of less doubt in its determination.

No. 375 S. Royal Ontario Museum of Palaeontology.

POLEUMITA HUDSONICA, *Parks*.

Plate IV, Figures 1 and 2.

POLEUMITA HUDSONICA, *pars.*, *Parks*. Bur. Mines of Ontario, 22nd Rep., pt. 1, p. 194, 1913.

In the preliminary report the specimen referred to this species was included with those which I have now removed to *Euomphalus rotundus*, leaving a single specimen as the type of the present species. This example is very badly preserved, but it seems to differ from any others in the collection and is worthy of a brief description, which must be regarded as provisional only.

The fragment indicates a shell of about 56 mm. in maximum diameter; the body whorl is relatively very large with a height of about 22 mm. The spire is very low and small. There are not more than three whorls in a complete shell. The specimen is a cast of the interior only and shows no ornamentation on the whorls of the spire, but the body whorl shows four prominent revolving ridges separated by shallow concavities of which the upper is broader, the middle medium and the lower narrowest. The upper surface of the body whorl is flat and apparently smooth; the lower surface is not revealed except in one small spot, where it also appears to be smooth.

The low spire induces me to ascribe the species to *Poleumita* rather than to *Gyronema*, but the distinctness of the revolving ridges suggest a Trochonemoid shell. Although the specimen is very badly preserved, it is quite evident that it does not belong to any of Whiteaves' species of *Gyronema*, and it is certainly distinct from any other specimen in the collection with the exception of one of the fragments referred provisionally to *Gyronema speciosum*. It is quite possible that this fragment belongs to the present species, in which case the under side of the body whorl should be ornamented with revolving striæ much closer set than the prominent lateral ridges shown in the figure.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 371 S. Royal Ontario Museum of Palaeontology.

STROPHOSTYLUS FILICINCTUS, *Whiteaves*.

STROPHOSTYLUS FILICINCTUS, *Whiteaves*. Geol. Sur. Can., Ann. Rep., Vol. XIV, pt. F, p. 54, 1904.

STROPHOSTYLUS FILICINCTUS, *Whiteaves*. Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 263, pl. 30, figs. 4, 5, 6, 1906.

One cast of the interior probably referable to this species. It most closely resembles figure 5 of Whiteaves' plate.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 358 S. Royal Ontario Museum of Palaeontology.

Cf. DIAPHOROSTOMA PERFORATUM, *Whiteaves.*

DIAPHOROSTOMA PERFORATUM, *Whiteaves.* Geol. Sur. Can., Ann. Rep., Vol. XIV, pt. F, p. 52, 1904.
DIAPHOROSTOMA PERFORATUM, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 261, pl. 29, figs. 7 and 7a, 1906.

One crushed and broken specimen with part of the shell preserved; it is referred to this species with much doubt.

Locality—Above Limestone rapids, Severn river, District of Patricia.
Horizon—Silurian.
No. 359 S. Royal Ontario Museum of Palaeontology.

Also two internal casts resembling this species but with a whorl rather drawn out on the inferior lateral margin. The whorl is consequently less symmetrical as to its superior and inferior lateral outline than in the other example referred to this species.

No. 383 S. Royal Ontario Museum of Palaeontology. Locality as above.

LIOSPIRA STEVENSONI, *sp. nov.*

Plate IV, Figures 10 and 11.

LIOSPIRA *sp. indet, Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 194, 1913.

This species is represented by two casts of the interior. The spire is greatly depressed with an apical angle of about 125°. The body whorl is relatively large and the whorls of the spire small. The maximum diameter of the largest shell does not exceed 15 mm. The whorls present a sharp keel at about the mid height; above, the outline is at first concave and then convex to the suture, which is but slightly marked; below, the outline is very slightly concave and then rounded. Surface markings, umbilicus and aperture unknown.

These little casts are very different from any other species in the collection, and appear to belong to *Liospira*; the specific name is for Professor Geo. S. Stevenson of the University of Toronto, whose death occurred on the day this account was written.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 401 S. Royal Ontario Museum of Palaeontology.

TROCHUS (?), *sp. indet.*

Plate III, Figure 7.

TROCHUS *sp.*, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. I, p. 194, 1913.

This species is represented by a small and imperfect cast of a trochiform shell, somewhat resembling *Trochus gothlandicus*, Lindström.[1] Ulrich regards this species as a derivative from *Raphistominia* and expresses great doubt as to the systematic position of the whole assemblage of forms ascribed to *Trochus* by Lindström. That author himself is very doubtful as to these forms, and we may therefore regard these Silurian trochiform shells as of undetermined relations. Whatever may be the proper position of this type of shell, there is no doubt that they are well represented in the Silurian of Gotland, and that they are represented by two and possibly more species in our collection. *Murchisonia hercyna*, Billings, (*M. billingsana*, Miller) from the Guelph of Ontario is referable to the same general type.

The present specimen shows portions of three whorls only; the lower one is about 14 mm. wide and 4.5 mm. high. The apical angle is moderate (45°), the sutures but slightly impressed, and the outline of the whorl is almost straight from suture to suture. On one side the body whorl is much less inclined, but this feature may be due to deformation before the interior was filled with matrix. The specimen is quite indeterminate specifically, but it is worthy of mention as typical of this trochiform class of shells.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 367 S. Royal Ontario Museum of Palaeontology.

TROCHUS (?), *sp. indet.*

Plate III, Figure 14.

One cast of a small trochiform shell about 11 mm. wide and practically the same height. Volutions four or five. Probably imperforate. Apical angle 55 degrees. External face of whorls practically straight conforming to the shape of the shell. Base flat.

The species is quite indeterminable, but the form is evidently related to the species described above; it represents a second variety of trochiform shell and may be compared with some of the species described by Lindström from the Silurian of Gotland.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 402 S. Royal Ontario Museum of Palaeontology.

---

[1] Sil. Gast. and Pter. of Gotland, Lindström, Stockholm, 1884.

GASTROPODA, *indet.*

In addition to the more or less distinct and determinable Gastropoda already listed, the collection contains a number of fragments which evidently belong to still other species, but which are quite incapable of determination. Brief notes on these specimens follow:

Fragment of mould of the exterior. Indicates a shell of about 60 mm. in diameter and about 35 mm. high. Four whorls shown; probably six or seven in all. Whorls rounded above and slightly concave on the lower lateral aspect. A wide alar expansion extending at least 10 mm. from the periphery of the body whorl and marked by fine curved lines of growth. This expansion is not observed on the upper whorls, but its probable existence cannot be denied. There is some evidence of a raised band on the superior lateral aspect of the whorls. Apical angle about 70°.

Probably a *Euomphalopterus* of the type of *E. velaris*, Billings sp. or *E. valeria*, Billings sp. Silurian, Limestone rapids, Severn river.

No. 372 S. Royal Ontario Museum of Palaeontology.

Fragment of the cast of a body whorl indicating a shell 48 mm. in diameter. The outline is very sloping above and obtusely rounded at the inferior edge. The height measured in the direction of the sloping side is 11 mm., while the direction at right angles, *i.e.*, the thickness of the whorl, is only 7 mm. None of the described species possess a body whorl of this character. Silurian, Limestone rapids, Severn river.

No. 373 S. Royal Ontario Museum of Palaeontology.

Fragment of a body whorl indicating a turreted type of shell. The whorl is 17 mm. high; it is distinctly concave on the superior lateral aspect for a width of 7 mm. from the suture to a sharply marked revolving ridge. Below the ridge the outline is again broadly concave to near the inferior lateral margin, beyond which it is convex. This shell is distinctly different from any other described in this contribution; it suggests the genus *Lophospira*. Silurian, Assina rapids, Severn river.

No. 374 S. Royal Ontario Museum of Palaeontology.

Two fragments of casts probably referable to *Coelidium* or to *Hormotoma*. One is slightly angulated a little above the mid-height, and the other shows a rounded whorl a little expanded in the lower half. The first of these specimens may belong to *Coelidium macrospira* and I should ascribe the second to *Hormotoma whiteavesi* except for the fact that the apical angle is larger than in the other specimens which I have placed in that species. Silurian, Limestone rapids, Severn river.

No. 376 and 377 S. Royal Ontario Museum of Palaeontology.

Mould of the exterior of a small trochiform shell. Basal diameter 16 mm. Height 11 mm. Sides flat. Sutures scarcely visible. Whorls marked by three rounded ridges separated by sharp depressions. Silurian, Limestone rapids, Severn river.

No. 378 S. Royal Ontario Museum of Palaeontology.

Fragment of the cast of a body whorl of a small shell of about 13 mm. in diameter. The whorl is rounded above and with a sharp peripheral keel at the lower margin. While much smaller than *Euomphalopterus valeria*, the fragment has almost exactly the outline of this species as figured by Whiteaves. (Geol. Sur. Can., Palaeoz. Foss., Vol. III, pl. fig. 1a. Silurian, Limestone rapids, Severn river.

No. 379 S. Royal Ont. Museum of Palaeontology.

Imperfect cast of a small shell with rounded whorls and deep sutures suggesting the genus *Holopea*. Silurian, Limestone rapids, Severn river.

No. 380 S. Royal Ontario Museum of Palaeontology.

One distorted internal cast suggesting *Strophostylus filicinctus*, Whiteaves. See page 67. Silurian, Limestone rapids, Fawn river.

No. 381 S. Royal Ontario Museum of Palaeontology.

Fragments of moulds of the apical side of a large shell which may possibly be the form herein described as *Pycnomphalus colemani* but which could not be referred to any other species of this report. Silurian, Limestone rapids, Severn river.

No. 382 S. Royal Ontario Museum of Palaeontology.

Fragment of a cast of a small *Euomphalus* about 15 mm. in maximum diameter. The spire is slightly ascending. The body whorl is obtusely sub-angular above and rounded below. Apparently differs from any other species in the collection. Silurian, Severn river.

No. 411 S. Royal Ontario Museum of Palaeontology.

MULTISPIRAL OPERCULA OF GASTROPODS.

The collection contains three multispiral opercula derived from two different species. One type shows a diameter of 16 mm. with about six coils; the other is somewhat larger, 26 mm. in diameter with an indeterminate number of coils.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.

No. 416 S. Royal Ontario Museum of Palaeontology.

CEPHALOPODA

ENDOCERAS HUDSONICUM, *Parks.*

Plate V, Figure 10.

ENDOCERAS HUDSONICUM, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 195, 1913.

This species is founded on one broken and very unsatisfactory fragment. A restoration of the outline presented by the fragment would indicate an elliptical shell about 110 mm. by 75 mm. Although the specimen is broken and probably somewhat deformed, I am of the opinion that the shell was elliptical rather than round.

The septa are rather closely placed for a shell of this size—about 7 mm. apart: at a point where the siphuncle is 20 mm. from the shell the septa extend 20 mm. forward to their sutures.

The siphuncle is apparently round and about 35 mm. in diameter; it is within 20 mm. of the shell on one side and 50 mm. at 90°. Directly opposite to the first measurement the distance cannot be ascertained. The siphonal funnels are tubular and reach almost if not quite to the septum next apicad.

Vertical sections show considerable displacement of the funnels and the complete absence of an inner sheath or other endosiphuncular structures. In view of the fragmentary nature of the specimen it is perhaps unwise to establish a species but the inaccessible nature of the locality of occurrence must serve as an excuse for so doing. I am further impelled to this action by the fact that the genus *Endoceras* is rare if not absent among Silurian *Cephalopoda* hitherto described. It should be noted however that Whiteaves records the occurrence of *Endoceras* or *Nanno* from the Silurian rocks of the Ekwan river. We are perhaps dealing with the same species referred to by him on page 263, Volume III of Palaeozoic Fossils.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 322 S. Royal Ontario Museum of Palaeontology.

ORTHOCERAS (?), *sp. indet.*

One small fragment of a brevicone, but worthy of mention because quite distinct from any other form in the collection.

Shell circular, 13 mm. in diameter at anterior end. In a length of 10 mm. it decreases to a diameter of 7 mm. Septa about 1.5 mm. apart. Sutures straight. Siphuncle not observed. Shell absent.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 341 S. Royal Ontario Museum of Palaeontology.

ORTHOCERAS, *sp. indet.*

Several fragments of an orthoceracone indicating a diameter of from 30 to 40 mm. Septa about 6 mm. apart. Siphuncle only faintly indicated; sub-central in position.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 334 S. Royal Ontario Museum of Palaeontology.

ORTHOCERAS, *sp. indet.*

Plate V, Figure 12.

One fragment of a small orthoceracone or cyrtoceracone. The chamber of habitation is 26 mm. long; it is apparently round with a diameter of 15 mm. There is evidence of a very slight curvature and a slight contraction towards the aperture. The septa are strongly curved and about 2 mm. apart. The sutures are not discernible but a central siphuncle seems to have been present. The form is possibly identical with *Orthoceras ommanneyi*, Salter. (See "Sutherland's Journal, etc.")

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 335 S. Royal Ontario Museum of Palaeontology.

ACTINOCERAS HEARSTI, *Parks.*

Plate VI, Figure 5.

ACTINOCERAS HEARSTI, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. I, p. 195, 1913.

This species is founded on one well preserved specimen showing the siphuncle, portions of eight cameræ, and part of the outer shell.

The shell is apparently round and very gently tapering, having in the specimen a diameter of 112 mm. The septa average 11.5 mm. apart; on the siphonal side of the siphuncle they are bent sharply orad but on the anti-siphonal side their curvature is more gentle.

The siphuncle shows a maximum width of 50 mm.; it is strongly nummuloid with the rings inclined at a slight angle to the axis. On the internal side the rings are evenly rounded, while on the external side they have an orad aspect in conformity with the highly curved septa. The siphuncle is marginal in position lying within 3 mm. of the shell at the posterior end and 6 mm. at the anterior end of the specimen.

The endosiphuncle is narrow, apparently about 6 mm. wide; it is somewhat excentric being placed nearer to the internal side of the siphuncle. The radiating tubuli seem to have been carried on infundibuliform membranes as in *Huronia inflecta* (page 75); but in the present species these structures do not arise at so low an angle from the endo-

siphuncle and they seem to terminate towards the centre of the rings. Although there is no direct evidence that the tubuli communicated with the cameræ I have every reason to believe that such was the case by comparison with another example of the species (*vide postea*).

This species is of the type of *Orthoceras* (*Actinoceras*) *crassiventre*, Wahl. as figured by Barrande in Plate 233, Systême Silurien de la Bohême. It differs in the much greater width of the siphuncle for a given height of segment. *Actinoceras hearsti* is also closely related to a species from the Trenton of Manitoba ascribed by Whiteaves to *A. richardsoni* and figured in Volume IX, Section IV, Transactions of the Royal Society of Canada. The Royal Ontario Museum contains specimens of this form which have been cut and polished; they resemble Whiteaves' figures, but they show neither the calcareous lamellae or the direct tubuli characteristic of *A. richardsoni*. The species is named for the Honourable W. H. Hearst, Premier of Ontario, on whose initiative the Hudson Bay Exploring Expedition of 1912 was organized.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 314 S. Royal Ontario Museum of Palaeontology.

ACTINOCERAS, *sp. nov.*

Plate II, Figure 3.

ACTINOCERAS *sp.*, *Parks.* Bur. Mines, Ont., 22nd Rep., pt. I, p. 196, 1913.

The specimen consists of two siphuncular rings, very different from any others in our collection and from any figured by Bigsby or Stokes.

The segments are elliptical with a greater diameter of 55 mm. and a shorter diameter of 45 mm. On the inner side the rings are evenly rounded and 11 mm. thick; on the outer side they are much flattened posteriorly and have a thickness of 13 mm. This flattening of the rings indicates a marginal position for the siphuncle, and the greater thickness may indicate a curved shell with the siphuncle on the convex side. The rings are inclined at an angle of more than 45 degrees to the axis of the siphuncle; this could occur only in a shell with septa arched forward to a remarkable degree.

The endosiphuncle seems to have been a distinct tube, 12 mm. wide and apparently possessed a proper wall.

This form is unique in our collection and apparently represents an undescribed species, I hesitate, however, to give it a specific name in view of the very incomplete nature of the specimen.

Locality—Assina rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 313 S. Royal Ontario Museum of Palaeontology.

HURONIA INFLECTA, *sp. nov.*

Plate VI, Figure 4.

Cf. HURONIAE . . . *Stokes.* Transactions Geol. Soc., ser. II, Vol. V, pt. 3, p. 710, pl. XL, fig. 2, 1840.

Cf. HURONIA *sp.*, *Barrande.* Syst. Sil. de la Bohême, pl. 231, fig. 2, 1866.

Cf. ACTINOCERAS BIGSBYI, *Whiteaves.* Trans. Royal Soc. Can., Vol. IX, sec. IV, p. 84, pl. X, fig. 2, 1891.

This species is represented by one specimen in our collection, which is undoubtedly very close to that figured by Stokes and copied by Barrande. Both these authors have hesitated to found a species on a single siphuncle but the discovery of another practically identical specimen at quite a different locality seems to justify that action at the present time.

The specimen consists of a portion of a siphuncle 85 mm. in length showing parts of six siphuncular rings. Nothing is known of the shell. The rings have a height of 15 mm. and a diameter of 45 mm.; they are disposed at a low angle to the axis of the siphuncle. In vertical section the septa are seen to extend well inward and to be in contact with the posterior face of the ring next orad, almost to the outer limit of the ring; along this line of contact there is a slight inward inflection of the septum. From the point where the ring parts from the septum behind it, it is evenly rounded and with an orad aspect. On coming in contact with the septum next orad, there is a sharp, tongue-like inflection apicad. This peculiar arrangement of rings and septa gives a strong forward inclination to the latter, which are only 10 mm. apart normal to their direction, while the actual height of a ring is 15 mm.

The endosiphuncle is narrow and rather indistinct with an average diameter of 7 mm. Annular outgrowths of the endosiphuncle spring at a low angle, sweep gently apicad and then turn outwards in a graceful curve terminating near the little tongue-like inflection of the siphuncular rings. From the point of origin of one of these outgrowths to its most posterior extension is 23 mm. Judging from the continuity of these structures, they appear to represent infundibuliform membranous or calcareous outgrowths, rather than radiating tubuli. It is of course likely that the membranous expansions carried tubuli, but there is no evidence that they penetrated the siphuncular sheath, although the exterior of the rings is well shown in parts of the specimen.

Our specimen differs from that figured by Stokes only in proportions, as Stokes' figure shows rings 20 mm. high for a width of 32 mm., while our specimen has rings 15 mm. high for a width of 45 mm.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 310 S. Royal Ontario Museum of Palaeontology.

OOCERAS, *sp. indet.*

A cast of the chamber of habitation and of a portion of the septate region of a small, laterally compressed, rapidly tapering cyrtoceracone. The two specimens doubtfully belong to the same species.

The body chamber of one specimen is 19 mm. long. At the posterior end, it measures 12.5 by 10 mm. Transverse section ovate, with the narrow part on convex side of shell. Contracts rapidly towards aperture. Nature of aperture not indicated.

The second fragment is 20 mm. long. Section elliptical or slightly ovate. Anterior diameter 12 mm. (dorso-ventral) and 9 mm. (lateral). Posterior diameters 8.5 and 7 mm. respectively. Medium curved. Exogastric. Septa 1.6 mm apart. Sutures with a slight lateral lobe and dorsal and ventral saddles.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 336 S. Royal Ontario Museum of Palaeontology.

OOCERAS (?), *sp. nov.*

Plate III, Figure 4; Plate VI, Figures 3 and 8.

Two fragments probably referable to the same species; they indicate a medium sized, laterally compressed, slowly tapering, exogastic cyrtocone. The cross section is elliptical rather than ovate. The smaller specimen is 33 mm. long and shows 14 cameræ in that distance. The anterior diameter is 25 mm. (dorso-ventral) and 20 mm. (lateral). The posterior diameter is 20 mm. by 16 mm. On the convex side the anterior septa are 3 mm. apart and the posterior septa are scarcely 2 mm. apart.

The sutures are fairly even, with perhaps a slight lateral lobe. The siphuncle is of fair size, nummuloidal, and marginal in position.

The second specimen is larger and shows part of the body chamber, which is at least 43 mm. long with a diameter of 31 mm. The septa average 3 mm. apart. The siphuncle is nummuloidal, marginal, and 10 mm. in diameter. There is some evidence of a contraction of the living chamber towards the aperture.

These two specimens indicate shells of similar structure, and they are possibly but not certainly of the same species. Both show characters pointing to the genus *Ooceras* as emended by Foord, or to *Maelonoceras* of Hyatt. In the absence of any striking specific peculiarity it would be ill advised to establish a species on material of such imperfect preservation.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.
No. 330 S. Royal Ontario Museum of Palaeontology.

PHRAGMOCERAS WHITNEYI, *Parks*.

Plate III, Figure 5; Plate VI, Figure 2.

PHRAGMOCERAS WHITNEYI, *Parks*. Bur. Mines of Ont., 22nd Rep., pt. 1, p. 194, 1913.

This example is a remarkably large representative of the genus; in fact I have seen no greater figured. The species is founded on one cast of the chamber of habitation obtained by Mr. Tyrrell at the Limestone rapids, Severn river, and a portion of the septate shell found at Assina rapids on the same stream. There is no immediate proof that the two specimens belong to the same species, but the general agreement in size, the absence of more likely associations, and the similarity of the stone point to the identity of the two specimens.

The dorso-ventral diameter of the shell at the anterior septum is 108 mm. The lateral diameter at the same point is 30 mm., and it may possibly be a little greater, as one side of the cast is somewhat worn. The height of the body chamber is 130 mm., and the maximum width from "ear" to "ear" is 150 mm. The ventral margin of the body chamber is strongly concave and well extended towards the aperture. The dorsal margin is convex, but the curvature is less pronounced than on the concave side. The aperture is reduced to a narrow slit medially: on the ventral side it is about 25 mm. wide, and it is not preserved on the dorsal side. The maximum lateral diameter of the body chamber is 50 mm. The cast shows faint indications of vertical fluting with the furrows about 4 mm. apart.

The first septum is strongly curved; a straight line joining the dorsal and the ventral extremities of this septum passes 27 mm. above the point of greatest curvature.

The septate portion measured along the median line shows a length of 200 mm. but this by no means represents the whole length of the septate shell, as the specimen does not show the apex. In this length are 14 cameræ which do not indicate a lessening spacing of the septa towards the apex. The first and second cameræ are about 10 mm. high; the sixth and seventh are 15 mm. high; owing to breaking and the consequent impossibility of ascertaining the median line, the height of the more apicad cameræ cannot be given.

This fine species is doubtless related to *P. lineolatum*, Whiteaves (Page 78), but it differs in the very much greater size and in the fact that the cross section does not show the attenuated ventral margin figured for *P. lineolatum*.

The species is named for the late Honourable Sir James Pliny Whitney, Premier and President of the Council, Province of Ontario.

Locality—Limestone rapids and Assina rapids, Severn river, District of Patricia, Ont.
Horizon—Silurian.
Nos. 318 and 319 S. Royal Ontario Museum of Palaeontology.

PHRAGMOCERAS LINEOLATUM, *Whiteaves.*

PHRAGMOCERAS LINEOLATUM, *Whiteaves.* Geol. Sur. Can., Ann. Rep., Vol. XIV, pt. F, p. 57, 1904.

PHRAGMOCERAS LINEOLATUM, *Whiteaves.* Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 265, pl. 34, figs. 1, 1a, 2 and 3, 1906.

PHRAGMOCERAS LINEOLATUM, *Parks.* Bur. Mines of Ont., 22nd Rep., pt. 1, p. 195, 1913

This species is probably represented by three specimens—one showing a chamber of habitation, and two exhibiting parts of the septate region.

Our specimens are large, slightly exceeding in size the largest one figured by Whiteaves. At the anterior septum our specimen measures 64 by 40 mm. The septa are 11 mm. apart on the convex or dorsal margin, and only 3 mm. apart on the ventral margin.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 317 S. Royal Ontario Museum of Palaeontology.

PENTAMEROCERAS RARUM, *sp. nov.*

Plate III, Figure 6.

One small specimen showing the body chamber with part of the test preserved. The character of the aperture is well shown by the cast of the interior, which projects beyond the preserved portion of the shell.

The chamber of habitation is of elliptical shape, with a maximum diameter of 18 mm. and a minimum diameter of 15.5 mm. The shell contracts rapidly towards the aperture, producing a narrow hyponomic sinus, a median dorsal sinus and two lateral sinuses. The cast of the hyponomic sinus indicates a length of 12 mm.; the median sinus a length of 5 mm.; and the lateral sinuses lengths of 4.5 mm. (ventral) and 6 mm. (dorsal).

The test shows delicate, flexuous, transverse striations.

The type of the genus *Pentameroceras*, Hyatt, is *Gomphoceras mirum*, Barr. (Système Silurien de la Bohême, Pl. 478, Fig. XII, 1 and 2. Pl. 82, Figs. 17-25; Pl. 91, Figs. 7-14; Texte, Vol. II, Partie IV, p. 134.) The type of aperture characteristic of this genus seems to be extremely rare, for Barrande states "Cette forme de l'ouverture n'a été observée que dans une seule espèce, *Gomphoc. mirum* de la Bohême. . . . Tous ces spécimens ont été trouvés sur l'horizon de notre bande e2; les 3 petits, à Hinter-Kopanina et les 3 plus grands, à Lochkow".

Our species is remarkably like *P. mirum* and is comparable with the larger forms figured by Barrande. The most noticeable difference is

the relatively greater length of the hyponomic sinus in our specimen. Mr. Tyrrell is to be congratulated on the discovery in Patricia of a representative of this exceeding rare genus.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian—Compare e2 of Barrande.

No. 324 S. Royal Ontario Museum of Palaeontology.

SEPTAMEROCERAS, *sp. indet.*

A single cast of a small form, showing some evidence of the type of aperture characteristic of *Septameroceras*. Dorso-ventral diameter of chamber of habitation about 18 mm.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario. (Loose boulder not certainly local.)
Horizon—Silurian?

No. 327 S. Royal Ontario Museum of Palaeontology.

GOMPHOCERAS (?), *sp. indet.*

One fragment of a chamber of habitation showing a much contracted aperture, the character of which is not discernible. This seems to be a large form, probably 50 mm. or more in diameter.

Locality—Above Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.

No. 331 S. Royal Ontario Museum of Palaeontology.

BARRANDEOCERAS (?), *sp. indet.*

Plate VII, Figure 8; Plate V, Figure 11.

BARRANDEOCERAS *sp.*, *Parks*. Bur. Mines of Ont., 22nd Rep., pt. I, p. 195, 1913.

A fragment of an internal cast without septa or siphuncle. The specimen is 130 mm. long and shows an increasing curvature towards the posterior. The cross section is broadly ovate with the narrow end internal. The anterior dimensions are 29 and 25 mm. The posterior dimensions are 19 and 17 mm. The reference of the fragment to *Barrandeoceras* is of course conjectural only.

Locality—Limestone rapids, Severn river, District of Patricia, Ontario.
Horizon—Silurian.

No. 342 S. Royal Ontario Museum of Palaeontology.

TRILOBITA

BUMASTUS *cf.* IOXUS, *Hall.*

Plate IV, Figure 19.

BUMASTUS BARRIENSIS, *Hall.* Pal., N. York, Vol. II, p. 302, pl. LXVI, figs. 1-15, 1851.
ILLAENUS (BUMASTUS) IOXUS, *Hall.* 20th Rep., N. York State Mus., p. 420, pl. XXII, figs. 4-10, 1867.

One broken cephalon agreeing fairly well with Hall's species. The character of the facial suture seems to be slightly different from that shown in Hall's figures.

Locality—Limestone rapids, Severn river, District of Patricia.
Horizon—Silurian.
No. 426 S. Royal Ontario Museum of Palaeontology.

ENCRINURUS *cf.* PUNCTATUS, *Brunn.* sp.

Plate IV, Figure 20.

TRILOBUS PUNCTATUS, *Brunn.* Kjobenh. Sellsk. Skrivt. nye Samml., Vol. I, p. 394.
ENCRINURUS PUNCTATUS, *Emmrich.* Neues Jahrbuch für Min. Geol. and Pal., p. 42, 1844.
ENCRINURUS PUNCTATUS, *Vogdes.* Trans. San Diego Soc. Nat. Hist., Vol. I, no. 2, p. 67, pl. I, 1907. (See this article for extended synonomy and revision of the genus.)

Represented by one broken and exfoliated pygidium. The lateral margins and the extremity are not preserved; these are restored in the figure, but it must be understood that the characteristics of the tip of the pygidium and the pleural margins are not known.

The whole pygidium is about 9 mm. long and of about the same width at the anterior margin. The outline is triangular with a sharp posterior termination, but the presence or absence of a spine is not revealed. The axis is rather more than 4 mm. wide at the proximal end; it contains at least 20 segments and probably a few more. The distinct pleura are eight in number, but there is a little space in which possibly one more may occur. The specimen shows a deep and elongate pit between the segments towards the outer margin of the axis. As the specimen is decorticated the tubercles are very faintly shown, but there is evidence of their occurrence on the fifth, eighth and eleventh ring and less distinctly on the fourteenth. The pleural portion shows no sign of tuberculation, but considering the condition of the specimen, it cannot be concluded that no tubercles occur. In the number of the divisions of the axis and pleurae, the form is near *Encrinurus punctatus*, Brunn. The occurrence of tubercles does not seem to be a constant feature, and Salter mentions forms of the species from the Ludlow presenting only four, as in our specimen. The apparent absence

of pleural tubercles is the chief objection to ascribing our form to *E. punctatus*. The specimen cannot be ascribed to *E. lævis*, Anselm (*E. arcticus*, Salter), as the number of segments in the axis of the pygidium is much too great.

Locality—Limestone rapids, Fawn river, District of Patricia, Ontario.

Horizon—Silurian.

No. 427 S. Royal Ontario Museum of Palaeontology.

IV.

SPECIES FROM THE SILURIAN DRIFT.

ACERVULARIA AUSTINI, *Salter* sp.

STREPHODES? AUSTINI, *Salter*. Sutherland's Journal of Captain Penny's Voyage to Wellington Channel, etc., Vol. II, appendix, p. CCXXX, pl. 6, figs. 6, 6a, 1852.

ACERVULARIA AUSTINI, *Lambe*. Cruise of the Neptune, p. 322, 1906.

ACERVULARIA AUSTINI, *Parks*. Bur. Mines of Ont., 22nd Rep., pp. 192, 196, 1913.

The collection contains four specimens from different localities differing only in the size of the corallites which vary from 3 to 11 mm. in diameter. In one specimen the maximum diameter is 7 mm. In *A. austini* the maximum diameter is 8 mm. and Lambe states that the maximum of the specimens brought by Mr. Low from Beechey island is 10 mm. The finest of our specimens corresponds remarkably with *A. gracilis*, Billings, as redefined by Lambe. It is very likely that the mere size of the corallites is not of specific value and that *A. gracilis* is a synonym for *A. austini*, which antedates it. (See Lambe, *op. cit.*)

Salter's original description is as follows: "This fine coral which we dedicate with great pleasure to the gallant commander of the Expedition, is one of the most frequent species. It occurs in the form of rounded masses from an inch to several inches in diameter, covered on all sides with stellate cells—at first sight looking very like the *Astreæ* of the present seas. The internal structure, however, as of nearly all the corals of the older rocks, is quite of another order. Prof. McCoy, to whom I submitted these figures of the corals with drawings and notes has kindly given me his opinion on several of them. He would prefer to regard this as *Clisiophyllum* rather than *Strephodes* from the internal structure.

"Surface covered by hexagonal or pentagonal cells, of various sizes, the larger ones frequently four lines across, the smaller ones in groups of two, three, or more at the angles of the others. The extreme edges of the cups are thin and crenulated, their sides thickened and sloping steeply. In a large star they are radiated by about 30 or 40 equal blunt lamellæ, which extend to the base, and about half of them are there united in bundles of three or four, and are twisted on the surface of a low boss which rises from the centre. The lamellæ are united everywhere by frequent vesicular plates. A transverse section below the cup shows narrow but distinct divisional walls between the cells; and the lamellæ twisted in the middle and united loosely by the vesi-

cular tissue. The intermediate ones in the section appear longer than they are in the cup. A longitudinal section shows the vesicular plates arched a little upwards in the middle under the boss, then downwards and again inclined upwards in the outer area in two or three rows of cells. In these sections both the lamellæ and the transverse plates are thin, and the former are wavy,"

Localities—Drift, Mouth of the Nelson river; Drift, Mouth of Machichi river; Assina rapids, Severn river, District of Patricia, Ontario.

Horizon—Silurian?

Nos. 294 S., 295 S., 296 S. Royal Ontario Museum of Palaeontology.

PHRAGMOCERAS NELSONENSE, *sp. nov.*

Plate I, Figure 7; Plate III. Figures 1 and 2.

This species is founded on four fragments showing living chambers and one showing a portion of the septate shell.

The dimensions of the living chamber at the anterior septum are as follows in the different specimens:

	1	2	3	4
Dorso-ventral diameter....	25 mm.	29 mm.	.....	25 mm.
Lateral diameter.....	19 mm.	19 mm.	19 mm.	18 mm.

The height of the body chamber in the median line is from 30 to 35 mm. In no case is the outer shell preserved, but some of the casts show a bead-like ornamentation of the posterior margin with faintly marked longitudinal ribs extending upward therefrom. Both the ventral and the dorsal outlines of the living chamber are convex. The dorsal aperture is much the larger and the ventral aperture much smaller and situated at the extremity of a sharply drawn out, tube-like prolongation of the shell.

The septate region is rather sharply curved ventrally just beyond the living chamber, but the whole form of the septate shell is not revealed. The anterior septa on the dorsal margin are about 2.5 mm. apart. On the ventral side, they are slightly closer together and present a faint ventral saddle.

The siphuncle is small and is situated close to the ventral margin.

The indications of vertical fluting on the living chamber suggest *P. nestor canadense*, described by Dr. Whiteaves from the Guelph formation at Hespeler, Ont.[1] The present example, however, is much smaller, the dorsal aperture is more extended and the septate region is more curved.

[1] Geol. Sur. Can., Palaeoz. Foss., vol. III, p. 39, pl. 7, figs. 1, 1a and 1b.

A somewhat similar form from the Attawapiskat river was described by Whiteaves as *P. lineolatum*[1] but our specimens differ strongly in the convex instead of concave outline of the ventral margin of the living chamber.

A much closer resemblance is presented to *P. parvum*, Hall and Whitfield;[2] not so much to the type figure as to later drawings, *e.g.*, that by Whiteaves (Pl. VII, Fig. 2, Vol. III, Pal. Foss.) and those by Clarke and Ruedemann (Guelph Fauna in the State of New York, Mem. 5, N.Y. State Museum, pl. 21, figs. 1-8.) The sharply drawn out, ventral apertural tube, which is considered typical of *P. parvum*, as well as the general shape of the body chamber, is common with our species. On the other hand, *P. parvum* does not show the sharp curvature of the septate region, which is a striking feature of the new species.

Locality—Drift, near mouth of Seal river, Nelson river, District of Patricia, Ontario.
Horizon—Doubtful, but probably Silurian.
No. 316 S. Royal Ontario Museum of Palaeontology.

Two slabs of whitish-grey fine grained argillaceous limestone from the drift at York. The stone is full of impressions and casts of Ostracoda. The recognizable species are as follows:

ISOCHILINA GRANDIS LATIMARGINATUS, *Jones*. Geol. Sur. Can., Cont. to Can. Micro-Pal., Vol. I, pt. 3, p. 78, pl. 10, figs. 1a, b and c, and 3 and 4, 1891.
No. 421 S. Royal Ontario Museum of Palaeontology.

LEPERDITIA WHITEAVESII, *Jones*. Geol. Sur. Can., Cont. to Can. Micro-Pal., Vol. I, pt. 3, p. 87, fig. 6, p. 87, pl. 12, figs. 11, 12, 13 and 14, 1891.
No. 422 S. Royal Ontario Museum of Palaeontology.

LEPERDITIA HISINGERI, *Schmidt*. Mem. Acad. Imp., St. Petersbourg, ser. 7, Vol. XXXI, no. 2, p. 16, figs. 22 and 23, 1873; *Ibid.*, Vol. XXXI, no. 5, p. 14, pl. V, figs. 5-7, 1873.

LEPERDITIA HISINGERI, *Jones*. Geol. Sur. Can., Cont. to Can. Pal., Vol. I, pt. 3, p. 82, pl. 10, figs. 5 and 7; pl. 12, figs. 8 and 15; pl. 13, figs. 1, 2, 3, 4, 5, and 9. (See this article for extended synonomy.)
No. 420 S. Royal Ontario Museum of Palaeontology.

The slab contains several casts of *Leperditia* referable to the last species, but probably to be ascribed to some of the varieties described by Jones (*op. cit.*). *L. hisingeri fabulina* is probably present with others of Jones' varieties.

There can be little doubt that these slabs were derived from a Silurian horizon very similar to that at the north end of Lake Winnipegosis, Cedar lake and the Grand rapids of the Saskatchewan.

---

[1] Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 265, pl. 34, figs. 1, 1a, 2 and 3, 1906.

[2] Pal. of Ohio, Vol. 2, p. 151, pl. 8, fig. 10, 1875.

V.

SPECIES FROM THE DRIFT OF UNCERTAIN HORIZON.

ZAPHRENTIS, *sp. indet.*

A single specimen with the following characteristics: Corallum conical, almost straight with a slight curvature near the apex only, 35 mm. long, rapidly expanding to a diameter of 33 mm. in the length given. Exterior marked with transverse lines of growth and distinct septal furrows.

A vertical section shows septa and wavy, somewhat oblique but entire tabulæ in the lower third only. Assuming that no internal structures are lost, which is very doubtful, the calyx is remarkably deep with an oblique and almost straight floor. This form is externally very like *Petraia* sp. described as No. 298 S. It is possible that the two specimens are identical, but the evidence of the internal structure, bad as it is, points to a dissimilarity.

Locality—Drift, Mouth of Nelson river, District of Patricia, Ontario.
Horizon—Doubtful.
No. 299 S. Royal Ontario Museum of Palaeontology.

CYATHOPHYLLUM, *sp. indet.*

One fragment of a cylindrical and gently tapering corallite of about 25 mm. in diameter; it is silicified and very imperfect, but reveals the typical structure of *Cyathophyllum*.

At a diameter of 25 mm. 33 long primary septa extend almost to the centre of the corallite. Well developed septa of the second order alternate with the primaries and extend inwards two-thirds of the distance to the centre.

A peripheral zone, corresponding in thickness with the length of the secondary septa is filled with vesicular tissue, which appears in transverse sections as outwardly arched dissepiments. The central third of the corallite is closely tabulate.

A distinct epitheca is present and shows strong annular rugosities or lines of growth.

Locality—Drift, Mouth of Nelson river, Manitoba.
Horizon—Doubtful.
No. 290 S. Royal Ontario Museum of Palaeontology.

ACTINOCERAS *cf.* CLOUEI, *Barrande.*

Plate II, Figure 6; Plate VI, Figure 1.

ORTHOCERAS CLOUEI, *Barrande.* Syst. Sil. de la Bohême, pl. 432, figs. 1-6; pl. 433, figs. 1 and 2; pl. 434, figs. 1-5, 1870.

ORTHOCERAS CLOUEI, *Barrande.* Syst. Sil. de la Bohême, texte, Vol. II, partie III, p. 718, 1874.

Our specimen, which consists of a portion of a siphuncle only, is referred to this species with considerable assurance, although the identification of such material must be more or less doubtful.

The siphuncle shows nine nummuloidal rings in a length of 53 mm. These rings do not taper gradually, for the first has a diameter of 23 mm., the seventh a diameter of 21 mm., and the ninth a diameter of 23 mm. The rings are evenly rounded with a slight orad aspect and are somewhat oblique to the axis of the siphuncle. A vertical section shows that the constrictions between the rings are embraced by stout calcareous deposits which form a system of internal rings alternate with the true siphuncular expansions. These internal rings are separated by outwardly directed, slightly curved tubuli which seem to penetrate the siphuncular sheath. The interior of the siphuncle is thus constricted to a diameter of about 6 mm. in which, unfortunately, the endosiphuncle has been destroyed.

The very great similarity presented by Barrande's figures and the fact that the type of *Actinoceras clouei* was obtained from Newfoundland leads me strongly to believe that the specimens are co-specific.

Our form also presents a striking resemblance to the siphuncle figured but not named by Bigsby as Fig. 5, Pl. 30, Trans. Geol. Soc., Series II, Vol. I, 1824.

The present example differs from *Actinoceras keewatinense*, Whiteaves, in the relatively greater width and less height of the siphuncular rings, also in the slighter obliquity of the segments and in the absence of the regular taper of Whiteaves' species.[1]

Locality—Drift at York Factory.

Horizon—Doubtful.

No. 311 S. Royal Ontario Museum of Palaeontology.

OOCERAS CORDATUM, *sp. nov.*

Plate III, Figure 3.

This species is founded on a single fragment of a slowly tapering, laterally compressed cyrtocone. The transverse section is ovate with the narrow end external. Exogastric. The outer margin of the shell

[1] Geol. Sur. Can., Palaeoz. Foss., Vol. III, pt. IV, p. 246, pl. XXX, figs. 7 and 8, 1906.

is prominently marked by a longitudinal elevation which suffices for the determination of the species.

The specimen shows a portion of the septate region only. In a length of 40 mm. are 13 cameræ. At the fifth septum the dorso-ventral diameter is 22 mm. and the lateral diameter is 19 mm. The specimen is slightly distorted; a restoration would probably increase the dorso-ventral diameter. The sutures show a slight lateral lobe and a ventral saddle. The slow tapering, the lateral compression, the acute ventral shape, and the external siphuncle suggest the genus *Ooceras* as emended by Foord.

The peculiar elevated ridge along the venter is quite characteristic and seems to justify a specific name.

Locality—Drift of Nelson river, Manitoba.

Horizon—Uncertain.

No. 329 S. Royal Ontario Museum of Palaeontology.

INDEX

PAGE

Acervularia austini, *Salter* 82
Acervularia gracilis, *Billings* 82
Actinoceras anticostiense, *Billings* 24
Actinoceras bigsbyi, *Bronn* 23, 25
Actinoceras *cf.* clouei, *Barrande* 86
Actinoceras crassiventre, *Wahl* 74
Actinoceras hearsti, *sp. nov* 73
Actinoceras keewatinense, *Whiteaves* 86
Actinoceras richardsoni, *var.* magnum, *var. nov* 25
Actinoceras, *sp. nov* 23, 74
Actinostroma tenuifilatum, *Parks* 47
Amplexus coralloides, *Sowerby* 37
Amplexus severnensis, *sp. nov* 36
Aphyllostylus gracilis, *Whiteaves* 46
Ascoceras anticostiense, *Billings* 32
Ascoceras boreale, *sp. nov* 32
Ascoceras canadense, *Billings* 32
Ascoceras costulatum, *Whiteaves* 32
Atrypa, *sp. indet* 48
Aulocopella gigantea, *sp. nov* 8
Aulocopella winnipegensis, *Rauff* 9
Aulocopium 8
Barrandella mesoplicata, *sp. nov* 52
Barrandeoceras, *sp. indet* 79
Bellerophon nautarum, *Salter* 56
Bellerophon, *sp. indet* 55
Bellerophon (Cymbularia), *sp. indet* 56
Bumastus trentonensis, *Emmons* 33
Bumastus *cf.* ioxus, *Hall* 80
Bumastus, *sp. indet* 33
Byssonychia, *sp. indet* 35
Camarotoechia ekwanensis, *Whiteaves* 49
Clathrodictyon cystosum, *Rominger* 47
Clathrospira deiopeia, *Billings* 59
Coelidium macrospira, *Hall* 58, 70
Coelidium bivittata, *Hall* 58
Coelidium, *sp. indet* 58
Columnaria franklini, *Salter* 9
Columnaria rugosa, *Billings* 12
Conchidium decussatum, *Whiteaves* 51
Corals—*Incertæ sedis* 45
Cyathophyllum, *sp. indet* 85
Cycloceras, *sp. indet* 28
Cymatonota, *sp. indet* 35
Cymbularia rotunda, *Barrande* 56
Cymbularia, *sp. indet* 56
Cyrtoceras nitidium, *Barrande* 28

PAGE
Cyrtoceras, *sp. indet* 35
Cystiphyllum niagarense, *Hall* 37
Delthyris sulcatus, *Hisinger* 53
Delthyris, *sp. indet* 53
Dianulites petropolitana, *Dybowski* 15
Diaphorostoma perforatum, *Whiteaves* 68
Dinorthis pectinella, *Emmons* 16
Diphyphyllum 46
Discoceras shamattawense, *sp. nov* 31
Encrinurus arcticus, *Salter* 81
Encrinurus lævis, *Anselm* 81
Encrinurus punctatus, *Brunn* 80
Endoceras hudsonicum, *sp. nov* 72
Eotomaria durhamensis, *Whiteaves* 60
Eotomaria *cf.* galtensis, *Billings* 59
Eotomaria hopkinsi, *sp. nov* 60
Escharopora, *sp. indet* 15
Euomphalopterus alatus, *Wahl* 64
Euomphalopterus tyrrelli, *sp. nov* 63
Euomphalopterus valeria, *Billings* 64, 70
Euomphalopterus velaris, *Billings* 70
Euomphalopterus, *sp. indet* 70
Euomphalus minor, *sp. nov* 61
Euomphalus præcursor, *Lindstrom* 62
Euomphalus rotundus, *sp. nov* 61, 63
Euomphalus, *sp. indet* 62
Favosites aspera, *d'Orbigny* 9
Favosites hisingeri, *M-E. and Haime* 42
Favosites gothlandica, *Lamarck* 42
Favosites polymorpha, *Gold* 11
Fenestella subarctica, *Whiteaves* 48
Gastropoda, *indet* 70
Gastropoda (opercula) 71
Glassia variabilis, *Whiteaves* 49
Glassia variabilis, *var. nov* 49, 50
Gomphoceras mirum, *Barrande* 78
Gomphoceras, *sp. indet.* 79
Goniatites solitarius, *Barrande* 31
Gyronema dowlingii, *Whiteaves* 66
Gyronema speciosum, *Whiteaves* 66, 67
Halysites catenularia, *Linnaeus* 38
Halysites catenularia nitida, *Lambe* 38
Helicotoma 62
Holopea borealis, *Ami* 19
Holopea media, *sp. nov* 18
Holopea, *sp. indet* 71
Hormotoma acuminata, *sp. nov* 17
Hormotoma affinis, *Ami* 18
Hormotoma arctica, *Ami* 18
Hormotoma gracilis, *Hall* 18
Hormotoma patriciaensis, *sp. nov* 57

PAGE
Hormotoma whiteavesii, *Clarke and Ruedemann* 57, 70
Hormotoma winnipegensis, *Whiteaves* 57
Hormotoma, *sp. indet* 70
Huronia inflecta, *sp. nov* 73, 75
Huronia turbinata, *Stokes* 28
Huronia septata, *sp. nov* 27
Ilionia 55
Illaenus americanus, *Billings* 33
Isochilina grandis latimarginatus, *Jones* 84
Isotelus, *sp. indet* 34
Isotelus gigas, *De Kay* 34
Leperditia hisingeri fabulina, *Jones* 84
Leperditia whiteavesii, *Jones* 84
Liospira stevensoni, *sp. nov* 68
Liospira, *sp. indet* 35
Lituites bickmoreanus, *Whitfield* 31
Lophospira, *sp. indet* 70
Maclurea acuta, *sp. nov* 21
Maclurea bigsbyi, *Hall* 19, 22
Maclurea crassa, *Ulr. and Schofield* 19
Maclurea logani, *Salter* 19, 22
Maclurea magna, *Le Sueur* 19
Maclurea subovata, *sp. nov* 19
Maclurina manitobensis, *Whiteaves* 21
Megalomphala robusta, *Whiteaves* 56
Meristina expansa, *Whiteaves* 53
Meloceras, *sp. indet* 29
Modiolopsis 54
Modiomorpha acuminata, *sp. nov* 54
Monotrypa cumulata, *Ulrich* 15
Multispiral opercula 71
Murchisonia billingsana, *Miller* 69
Murchisonia chamberlini, *Whitfield* 59
Murchisonia hercyna, *Billings* 69
Nanno 72
Ooceras cordatum, *sp. nov* 76, 86
Ooceras, *sp. indet* 76
Oncoceras arcticum, *Schuchert* 29
Orthoceras anellum, *Conrad* 28
Orthoceras anticostiense, *Billings* 24
Orthoceras lepidodendroides, *sp. nov* 22
Orthoceras ommanneyi, *Salter* 73
Orthoceras, *sp. indet* 23, 72, 73
Orthodesma 35
Parastrophia 52
Pentamerus oblongus, *Sowerby* 51
Pentameroceras rarum, *sp. nov* 78
Petraia, *sp. indet* 43
Phragmoceras lineolatum, *Whiteaves* 77, 78, 84
Phragmoceras nelsonense, *sp. nov* 83
Phragmoceras nestor canadense, *Whiteaves* 83

PAGE
Phragmoceras parvum, *Hall* and *Whitfield* 84
Phragmoceras whitneyi, *sp. nov* 77
Plectambonites transversalis, *Wahl* 48
Plectorthis plicatella, *Hall* 16
Plethospira 59
Poleumita hudsonica, *sp. nov* 67
Poterioceras tyrrelli, *sp. nov* 29
Pycnomphalus colemani, *sp. nov* 65, 71
Pycnomphalus salaroides, *Whiteaves* 65
Pycnomphalus, *sp. indet* 65
Pycnostylus elegans, *Whiteaves* 40
Pycnostylus guelphensis, *Whiteaves* 39
Pycnostylus maximus, *sp. nov* 40
Pycnostylus, *sp. indet* 46
Rafinesquina alternata, *Conrad* 34
Rafinesquina lata, *Whiteaves* 17
Rafinesquina, *sp. indet* 17
Raphistominia 69
Rhynchospira lowi, *Whiteaves* 50
Rhynchotrema capax, *Conrad* 16
Rhynchotrema inæquivalvis, *Castelnau* 16
Rhynchotrema inæquivalvis subtrigonalis, *Hall* 16
Rhynchotrema minnesotensis, *Sardeson* 16
Septameroceras, *sp. indet* 79
Silurina distorta, *Barrande* 55
Silurina, *sp. indet* 55
Spirifer crispus, *Hisinger* 52
Spyroceras meridionale, *Whiteaves* 28
Strephodes pickthornii, *Salter* 15
Streptelasma corniculum, *Hall* 14
Streptelasma integriseptatum, *sp. nov* 13
Streptelasma robustum, *Whiteaves* 43
Streptelasma rusticum, *Billings* 12
Striatopora, *sp. indet* 11
Stromatopora constellata, *Hall* 47
Stropheodonta, *sp. indet* 49
Strophomena donnettii, *Salter* 49
Strophomena julia, *Billings* 17
Strophomena tetrastriata, *sp. nov* 16
Strophostylus filicinctus, *Whiteaves* 67, 71
Thoracoceras lepidodendroides, *sp. nov* 22
Trepospira kokeni, *Lindström* 62
Trochoceras insigne, *Whiteaves* 31
Trimerella ekwanensis, *Whiteaves* 50
Trochonema umbilicatum, *Hall* 19
Trochus gothlandicus, *Lindström* 69
Trochus, *sp. indet* 69
Tyrrellia 37
Whitella, *sp. indet* 34
Zaphrentis stokesi, *M. E. and Haime* 44
Zaphrentis, *sp. indet* 85

EXPLANATION OF PLATES.

Unless otherwise stated, figures are of natural size.

PLATE I.

PAGE

Fig. 1—*Discoceras* (?) *shamattawense, sp. nov* 31
The mould of the only specimen.

Fig. 2—*Pycnostylus maximus, sp. nov* 40
Portion of epitheca, ×2.

Fig. 3—*Pycnostylus elegans, Whiteaves* 40
Portion of epitheca, ×5.

Fig. 4—*Pycnostylus* (?) *sp. indet* 46
Portion of a decorticated epitheca, ×5.

Fig. 5—*Eotomaria hopkinsi, sp. nov* 60
Cast of the type specimen.

Fig. 6—*Coelidium, sp. indet* 58
Cast of three whorls. The dotted apex is restored.

Fig. 7—*Phragmoceras nelsonense, sp. nov* 83
Cast of the best preserved specimen showing the sharp angulation at the base of the living chamber.

Fig. 8—*Hormotoma patriciaensis, sp. nov* 57
Four whorls of the most perfect cast.

Figs. 9 and 10—*Pycnomphalus colemani, sp. nov* 65
Fig. 9, Apical view of cast. The inner whorls have been much restored.
Fig. 10, Basal view of cast. The inner ring represents the matrix lying above the umbilical callosity.

PLATE II.

Fig. 1—*Actinoceras richardsoni magnum, var nov* 25
Vertical section showing the tapering endosiphuncle, the calcareous lamellar filling of the siphuncle, the tubuli, and the septa.

Fig. 2—*Poterioceras tyrrelli, sp. nov* 29
Lateral view of cast. The beaded ornamentation at the rear of the body chamber is restored from other specimens.

Fig. 3—*Actinoceras, sp. nov* 74
Two segments of the siphuncle. The only specimen. Figure is inverted.

Fig. 4—*Orthoceras* (*Thoracoceras*) *lepidodendroides, sp. nov* 22
View of the type. Ornamentation restored but not emphasized. There is possibly a little too great an accord in the relation of the nodes to the septa. Cast.

Fig. 5—*Meloceras, sp. indet* 29
Lateral view of cast.

Fig. 6—*Actinoceras* cf. *clouei, Barrande* 86
Siphuncle of the only specimen.

Fig. 7—*Cycloceras* (?) *sp. indet* 28
The only specimen in the collection.

Figs. 8 and 9—*Ascoceras boreale, sp. nov* 32
Fig. 8, Dorsal view of the only specimen. Cast.
Fig. 9, Lateral view of the only specimen. Cast.

PLATE III.

Figs. 1 and 2—*Phragmoceras nelsonense, sp. nov*..... 83
Fig. 1, Lateral view of a broken cast of a small specimen showing the septate region. The concave margin is considerably restored and is doubtful.
Fig. 2, Lateral view of the chamber of habitation showing the beaded posterior margin.

Fig. 3—*Ooceras cordatum, sp. nov*..... 86
Lateral view of the only specimen.

Fig. 4—*Ooceras, sp. indet*..... 76
Lateral view of the septate portion.

Fig. 5—*Phragmoceras whitneyi, sp. nov*..... 77
Lateral view of the cast of the chamber of habitation, ×½.

Fig. 6—*Pentameroceras rarum, sp. nov.*..... 78
The only specimen. Shows portion of the test of the chamber of habitation and a cast of the aperture.

Fig. 7—*Trochus, sp. indet*..... 69
Cast of three whorls.

Figs. 8, 9 and 10—*Barrandella* (?) *mesoplicata, sp. nov*..... 52
Fig. 8, The pedicle valve.
Fig. 9, Anterior view of the same specimen.
Fig. 10, Lateral view of the same specimen.

Fig. 11—*Glassia variabilis, Whiteaves, var*..... 50
The pedicle valve.

Fig. 12—*Amplexus severnensis, sp. nov*..... 36
Interior of a corallite. Restored from several specimens, ×3.

Fig. 13—*Delthyris, sp. indet*..... 53
The only specimen, partly imbedded in matrix.

Fig. 14—*Trochus, sp. indet*..... 69
Cast with apex restored.

Figs. 15 and 16—*Euomphalopterus tyrrelli, sp. nov*..... 63
Fig. 15, Restoration of the type specimen. Size and general shape and curvature are correct. The ornamentation has been entirely restored from traces on the mould. The flat upper part of the whorl is possibly a little too wide, ×½.
Fig. 16, Vertical section through half of the shell, showing the shape and relationship of the whorls. The cast is shown in solid lines and the probable outline of the shell in dotted lines, ×½.

PLATE IV.

Figs. 1 and 2—*Poleumita hudsonica, sp. nov*..... 67
Fig. 1, Apical view, cast of interior.
Fig. 2, Lateral view, cast of interior.

Fig. 3—*Hormotoma acuminata, sp. nov*..... 17
Cast of interior.

Fig. 4—*Holopea media, sp. nov*..... 18
Cast of interior.

Fig. 5—*Bellerophon, sp. indet*..... 55
Cast of interior.

Fig. 6 and 7—*Bellerophon* (*Cymbularia*), *sp. indet* 56
Fig. 6, Umbilical view of cast.
Fig. 7, Median view of cast.
Figs. 8 and 9—*Euomphalus minor, sp. nov* 61
Fig. 8, Apical view of cast, ×2.
Fig. 9, Apical view of wax squeeze of mould of exterior, ×2.
Figs. 10 and 11—*Liospira stevensoni, sp. nov* 68
Fig. 10, Apertural view of cast.
Fig. 11, Apical view of cast.
Figs. 12, 13 and 14—*Modiomorpha acuminata, sp. nov* 54
Fig. 12, The left shell from a well preserved specimen.
Fig. 13, Cast of the right valve. The hinge apparatus and the posterior muscle scar are not preserved.
Fig. 14, Interior of left valve of a smaller specimen doubtfully of the same species. The posterior margin and the beak are broken and have been restored in dotted lines. The ventral part of the pallial line is not preserved but the hinge apparatus is well shown.
Fig. 15—*Whitella, sp. indet* 34
Cast of a left valve. The ventral and posterior margins are not exposed in the specimen. The dotted line is restored.
Fig. 16—*Strophomena tetrastriata, sp. nov* 16
Ventral valve and section of same.
Fig. 17—*Stropheodonta, sp. indet* 49
Pedicle valve natural size and portion of surface ×10.
Fig. 18—*Stropheodonta, sp. indet* 49
Decorticated pedicle valve much restored.
Fig. 19—*Bumastus* cf. *ioxus, Hall* 80
Cephalon with left side restored. Posterior margin uncertain.
Fig. 20—*Encrinurus* cf. *punctatus, Brunn* 80
Pygidium. Lateral margins not indicated, ×2.

PLATE V.

Figs. 1, 2, and 3—*Streptelasma integriseptatum, sp. nov* 13
Fig. 1, Vertical section.
Fig. 2, Transverse section.
Fig. 3, Tangential vertical section.
Figs. 4 and 5—*Streptelasma* cf. *rusticum, Billings* 12
Fig. 4, Vertical section.
Fig. 5, Transverse section.
Fig. 6—*Halysites catenularia, Linnaeus* 38
Vertical section ×2.
Fig. 7—*Aulocopella gigantea, sp. nov* 8
Vertical section.
Fig. 8—*Huronia septata, sp. nov* 27
Vertical median section of siphuncle restored. The vertical lines represent the vertical radiating lamellæ.
Fig. 9—*Silurina* (?), *sp. indet* 55
Cast of the only specimen. Note notch in anterior ventral margin.
Fig. 10—*Endoceras hudsonicum, sp. nov* 72
Vertical section through siphuncle and shell.

Fig. 11—*Barrandeoceras, sp. indet* 79
Outline of specimen (cast) in solid lines. Probable shape of shell in dotted lines.

Fig. 12—*Orthoceras, sp. indet.* cf. *O. ommanneyi, Salter* 73
Cast of the only specimen.

PLATE VI.

Fig. 1—*Actinoceras* cf. *clouei, Barrande* 86
Vertical section of siphuncle showing the internal thickenings and the direct tubuli.

Fig. 2—*Phragmoceras whitneyi, sp. nov* 77
Portion of septate region from cast of a specimen probably belonging to this species.

Fig. 3—*Ooceras, sp. nov* 76
Vertical section showing septa and siphuncle.

Fig. 4—*Huronia inflecta, sp. nov* 75
Vertical section of siphuncle.

Fig. 5—*Actinoceras hearsti, sp. nov* 73
Vertical section of portion of shell, showing siphuncle, endosiphuncle, tubuli and septa.

Fig. 6—*Actinoceras* cf. *bigsbyi, Bronn* 25
Vertical section of siphuncle.

Fig. 7—*Actinoceras bigsbyi, Bronn* 23
Vertical section through the siphuncle and the siphuncular side of the shell.

Fig. 8—*Ooceras, sp. nov* 76
Vertical section through a second specimen. Compare Fig. 3.

PLATE VII.

Figs. 1 and 2—*Maclurea acuta, sp. nov* 21
Fig. 1, Outline of volutions from the basal (flat) side.
Fig. 2, Vertical section through centre of shell.

Fig. 3—*Pycnomphalus colemani, sp. nov* 65
Vertical section. Cast in solid lines; shell in dotted lines.

Figs. 4 and 5—*Maclurea subovata, sp. nov* 19
Fig. 4, Outline of volutions from the basal (flat) side.
Fig. 5, Vertical section through centre of shell.

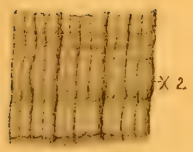
Figs. 6 and 7—*Euomphalus rotundus, sp. nov* 61
Fig. 6, Outline of whorls from apical side.
Fig. 7, Vertical section through centre of shell. Matrix below with some shell adhering. Casts of whorls in dotted lines.

Fig. 8—*Barrandeoceras* (?), *sp. indet* 79
Portion of cast of chamber of habitation.

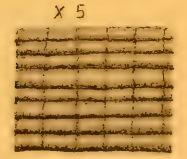
Fig. 9—*Pycnomphalus, sp. indet* 65
Vertical section through the only specimen. Casts of whorls in solid lines. Shell in dotted lines.

Fig. 10—*Euomphalus, sp. indet* 62
Vertical section through the only specimen. Matrix below with some shelly matter preserved. Cast of whorls in dotted lines.

1



2



3

4

5

6

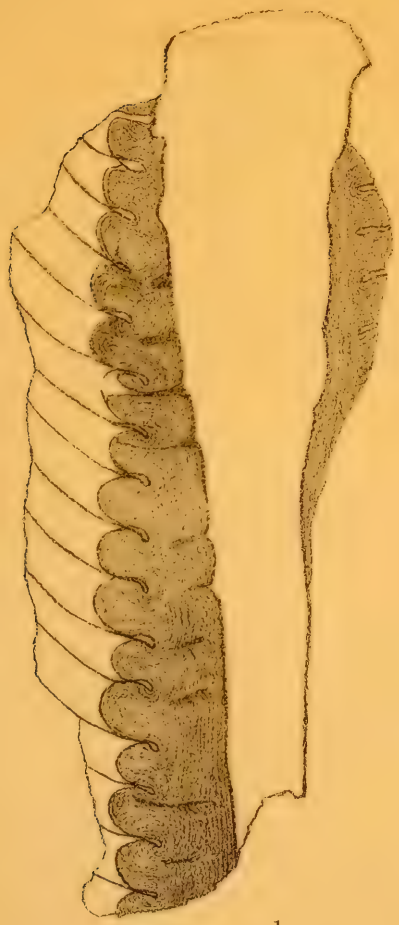
7

8

9

10

W. A. PARKS, DEL.



1

2

4

6

7

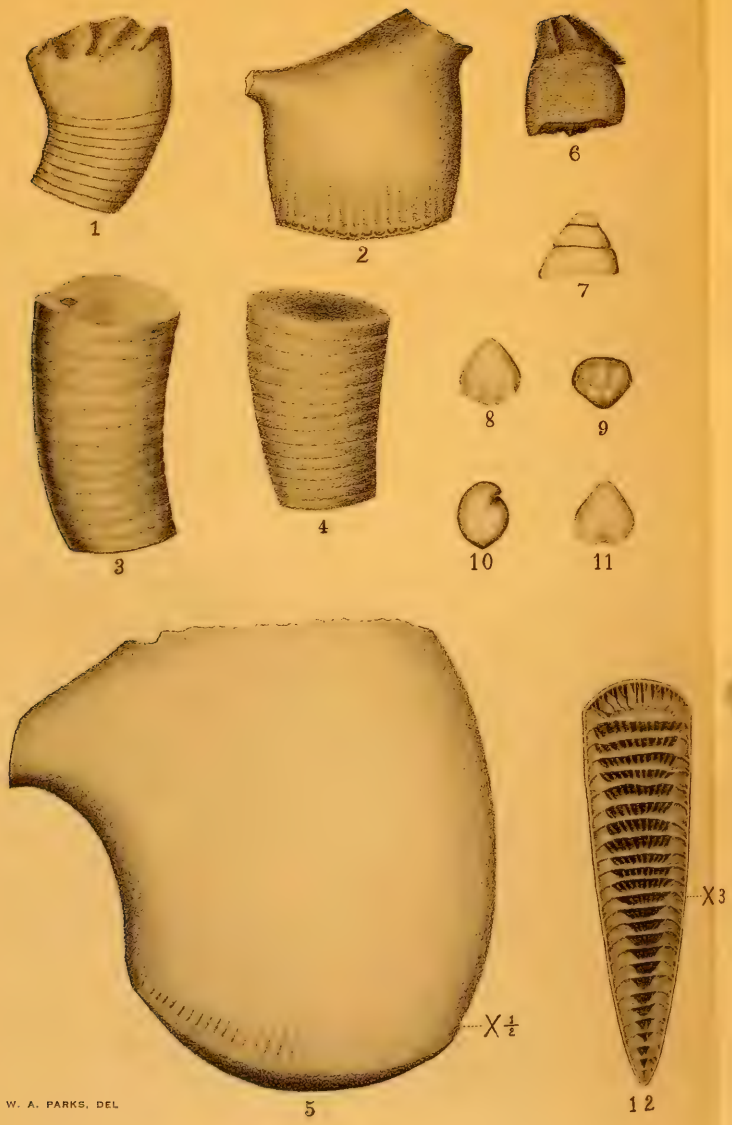
3

5

8

9

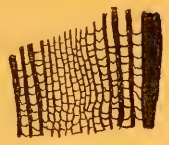
W. A. PARKS, DEL.



W. A. PARKS, DEL

W. A. PARKS, DEL.

1

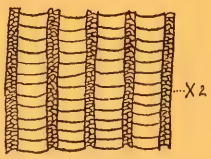


3

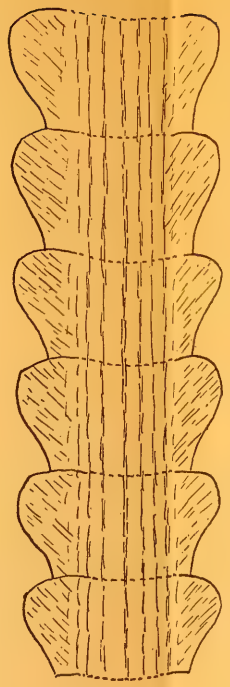
2

5

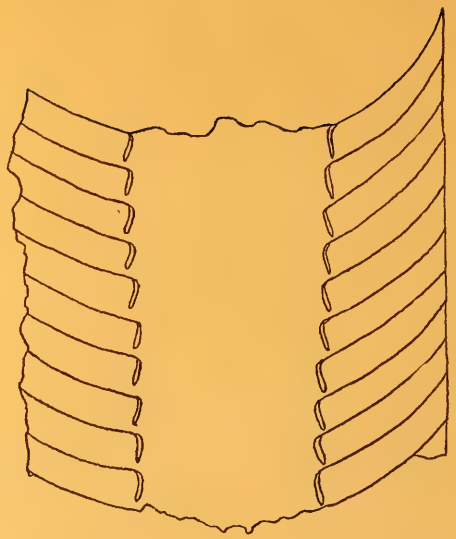
4



6

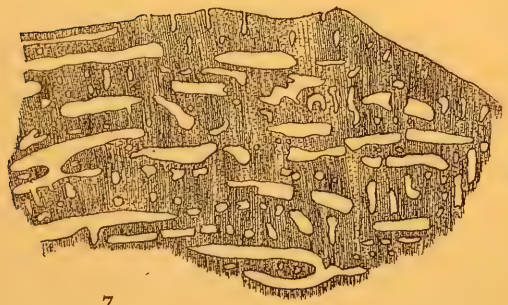


8

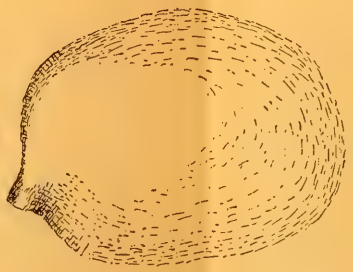


10

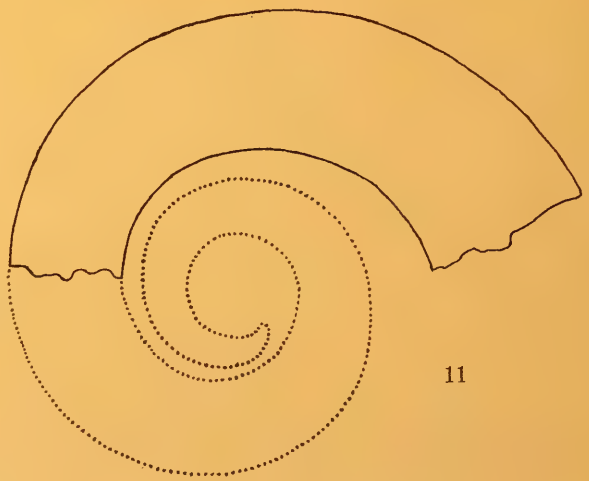
12



7



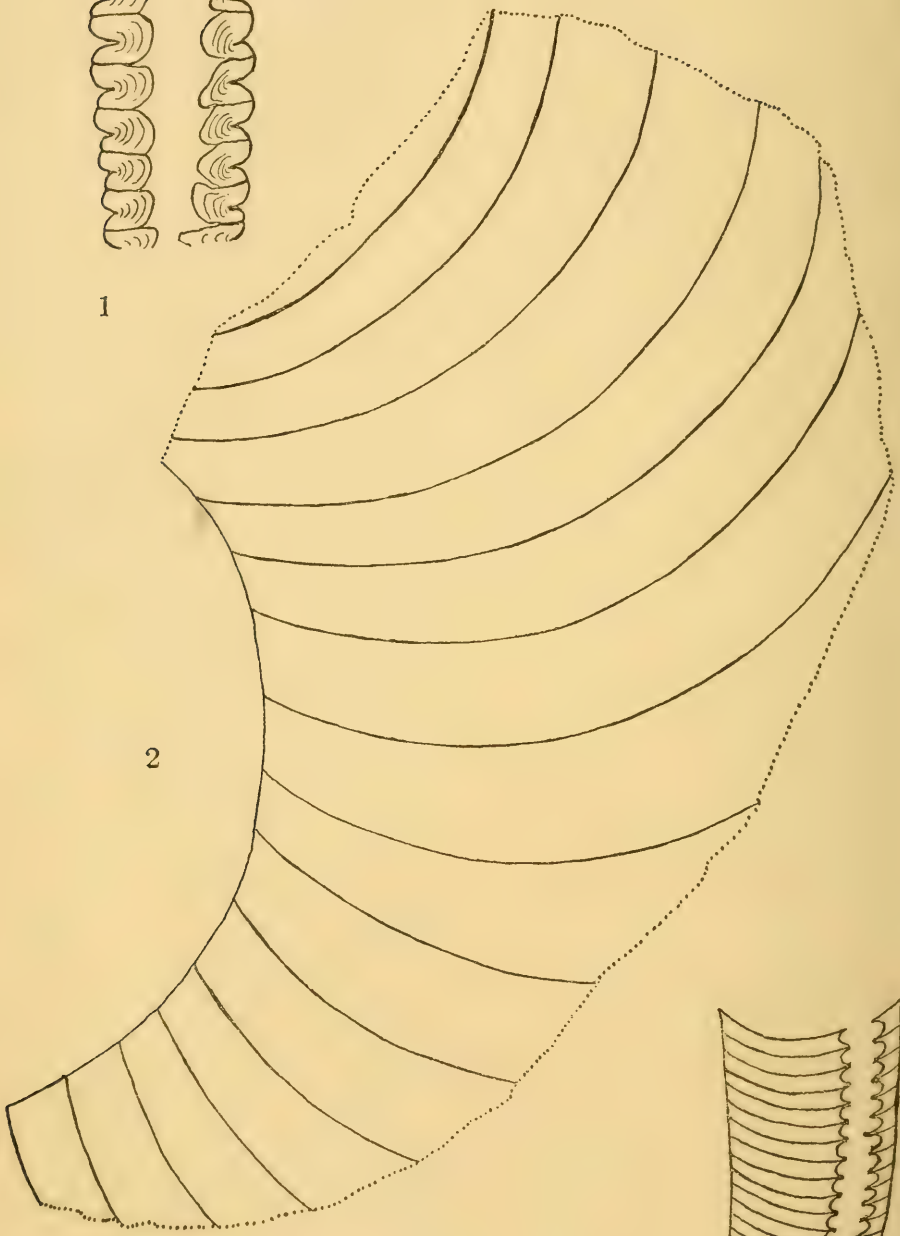
9



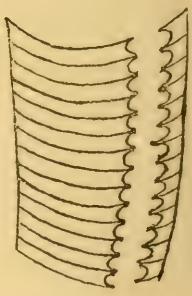
11

W. A. PARKS, DEL.

1



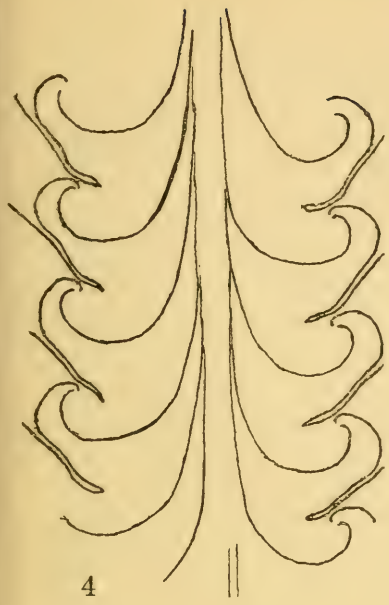
2



3

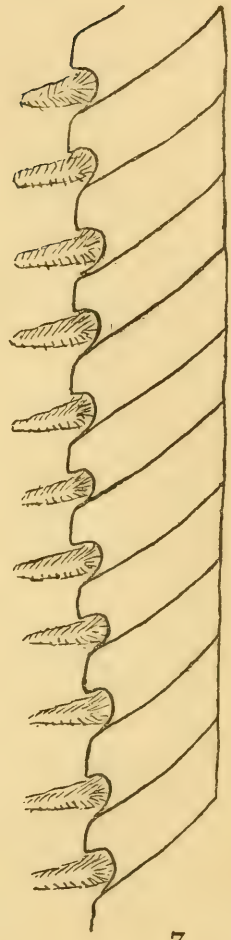
W. A. PARKS, DEL.

COCKAYNE,—BOSTON

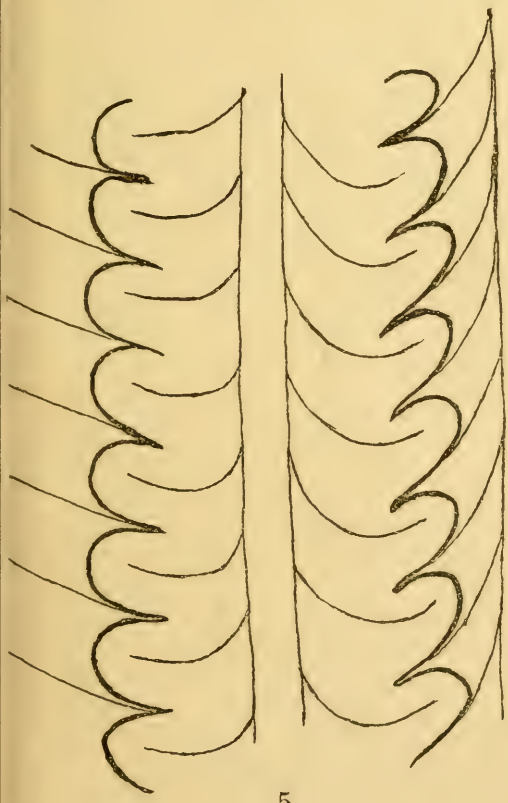


4

6

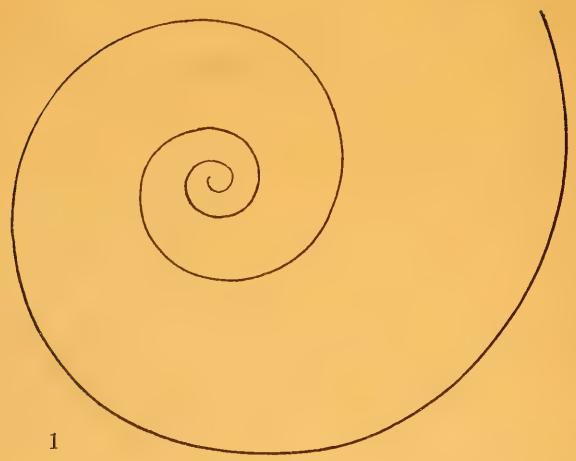


7

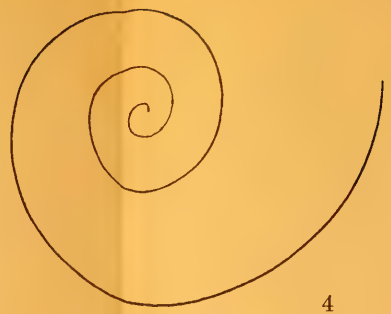


5

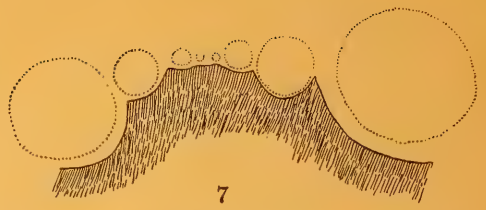
8



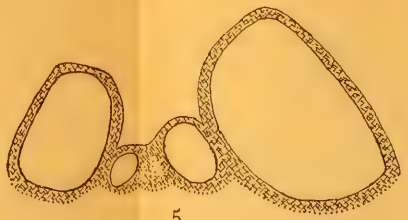
1



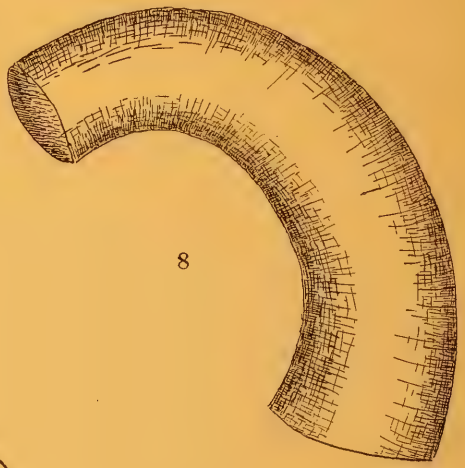
4



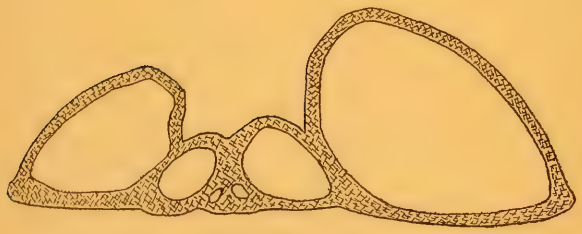
7



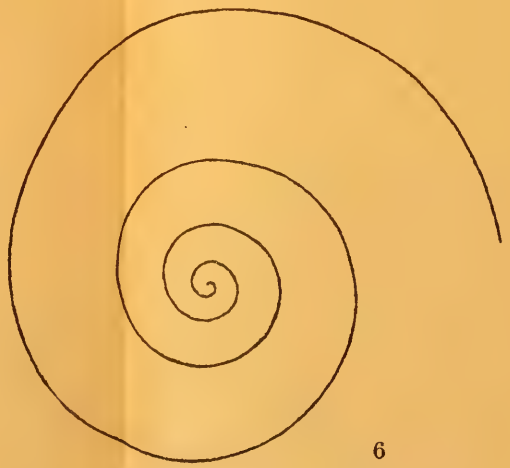
5



8



2



6

9

3

10

W. A. PARKS, DEL.

ON *CLUPEA PALLASII* CUVIER AND VALENCIENNES

By C. McLean Fraser, Ph.D.,
Curator of the Marine Biological Station, Nanaimo, B.C.

Plates VIII and IX

Spawning Habits

The points of resemblance in the Pacific herring (*Clupea pallasii*) and the Atlantic herring (*C. harengus*) are more noticeable than the points of difference, but although this is so, the points of difference are of sufficient importance to make interesting a special study of the life-history of the Pacific species. Even if there were not such differences it would be worth while, as there is so much unknown or in dispute in reference to the Atlantic species.

Judging from the description given in Jordan and Evermann,[1] one should expect to find the Pacific herring larger than the Altantic, but that does not seem to be the case in any herring of the Pacific Coast, with the possible exception of those around the shores of Northwestern Alaska. The Atlantic herring is said to be 16 inches in length, while the length of the Pacific herring is given as 18 inches. 16 inches may be a good length for an Atlantic herring, but certainly 18 inches is decidedly wide of the mark as a measurement of the herring that are fished now-a-days in the Strait of Georgia. Measurements of several hundreds of fish have been taken, and these have been collected from thousands of tons of fish, but no fish was obtained with a greater length than 10 inches, measured from the tip of the nose, or rather the lower jaw, to the beginning of the rays in the caudal fin. To be exact, the greatest length was 24.6 cm. or 9.8 inches. The average length was about 20 cm. or 8 in. The average of 80 females taken at various times throughout the year was 20.3 cm. while the average of the same number of males under similar conditions was 19.7 cm. The females averaged 106.2 grams (3.8 oz.) and the males 94.4 grams (3.4 oz.). These were caught with the seine and consequently included some that were quite small (as short as 15 cm.), but they would come very nearly being the average of the total catch of the season from this district.

[1] "Fishes of North and Middle America." Bulletin 47, U.S. National Museum, 1896, pp. 421-2.

The spawning habits of the Atlantic herring have been the cause of differences of opinion since the first investigation was made on this species, and even yet there is much lack of agreement concerning them. Are the winter herring and the summer herring the same, the individual spawning twice in the year or are they entirely different races, the individual spawning but once in the year but those of different races spawning at different seasons?

From all the evidence so far deduced there is not much room for such difference of opinion in the case of the Pacific herring. Apparently in no case has spawning been observed twice in the same year in any one district. The spawning time varies somewhat with the locality, as it does with either the winter herring or the summer herring in the North Sea, but in any one locality the spawning all takes place within a few days and there is no further indication of it until approximately the same time the next year. If a more extended series of observations corroborates what thus far seems quite certain, circumstantial evidence would indicate that the Atlantic herring spawn but once in the year, since the two species, in their general structure as well as in their habits, are so closely related. Direct investigation has been restricted almost entirely to the area within a radius of 20 or 25 miles from the Biological Station, Departure Bay, but as this area includes the most important herring district in British Columbia waters, it is large enough to provide material for a great amount of work, so much so, that what is already done can only be considered as a preliminary to a prolonged attack on the herring problem. The investigation is made all the more agreeable on account of the courtesy of the local representatives of the Fisheries Department as well as all others from whom it has been necessary to obtain information or assistance.

Within this area, during the seasons 1912-3 and 1913-4, the herring made their first appearance for the season at the entrance to Nanoose Bay, in 10-20 fathoms, about the first of October. At this time the gonads are partially developed, the eggs being from one-fourth to one-half the diameter of the full grown eggs. They remained in this vicinity in sufficient numbers for four or five weeks to make it profitable to fish for them and then they disappeared. About the same time a sufficient number appeared to the southward of Yellow Point to attract the fishermen in that direction. These localities are 30 miles or more apart, and it is scarcely probable that the same race of fish are found in the two places. If the one school travelled from one place to the other along the shore or even a short distance out, some of the fishermen, who at this time are continually on the lookout for them, would be sure to see some trace of them on the way. Furthermore, coho salmon caught in

October and November and spring salmon later off West Rocks and Five Finger Islands commonly contain mature herring. Seals killed in the vicinity of Nanoose Bay contained many of them, but as the seal is a strong swimmer it might go out some distance to sea when necessary to secure a sufficient supply of food. It is generally credited with a fondness for salmon, but there is plenty of evidence to show that the herring are not rejected, although they may be taken only when more tasty food is scarce. Such indications of the occurrence of herring in the neighbourhood is too common to make it possible to believe that even the larger body of those making their appearance early migrate southward soon afterward.

After fishing for a short time near Yellow Point the fishermen moved to Cowichan Gap (Porlier Pass), in the neighborhood of which they remained for several weeks, working gradually northwest from this again by way of Gabriola Pass and Northumberland Channel to points near Nanaimo, where the last fishing of the season (Feb. 28) was done. (Gill netting and line fishing is carried on more or less throughout the whole year). Practically all of the fishing until within a short time of the spawning season is done in much the same depth of water (15-25 fathoms).

For a week or two before spawning the Pacific herring are so devoid of fat that they are not very palatable and after they are spent they are no better for some time. For that reason as well as to protect them during spawning, restrictive regulations have been framed to prevent as much as possible the catching of them after they show signs of spawning.

In fish caught soon after spawning the gonads are so shrunken as to be scarcely noticeable, and they show but little change for two months or more. Then enlargement begins, but very slowly at first, so that even at the end of June, four months after spawning, each gonad usually weighs less than a gram. After this there are greater differences in development in different fish, probably depending somewhat on the age of the fish. At the end of six months they vary in weight from 2 to 4 or even 5 grams and are from one-quarter to one-half the size of the full grown gonad. The development during the last six months is as gradual as during the first six. At any one time the weight of the gonad bears a fairly definite ratio to the weight of the entire fish. The increase in the size of the egg will indicate the rate of enlargement of the gonad. Average eggs from fish obtained Oct. 10 were 0.7 mm. in diameter, Nov. 9, .85 to 0.9 mm., Dec. 12, 1.0 to 1.05, Jan. 28, 1.1 to 1.2; Feb. 8, 1.25 to 1.30; Feb. 22, 1.35 to 1.40; Feb. 28, 1.4 to 1.6 (spawned). This offers rather conclusive evidence that the Pacific herring at least spawns but once in the year.

It has been stated repeatedly by investigators who have worked on the North Sea herring that these come back to the identical place to spawn year after year. If one is to judge from the distribution of spawning areas in the spring of 1913 and 1914 that cannot be said of the Pacific species, as the distribution was quite different in the two years. In 1913 spawn was deposited thickly in Nanoose Bay well up at the head of the Bay and from there along the shore east all the way to Horswell Rock as well as everywhere in Departure Bay, while in 1914, there was none deposited at the head of Nanoose Bay, but there was some at the entrance to the Bay and for three or four miles to the eastward, but none the remainder of the way to Horswell Rock and none in Departure Bay.

Apparently there is not the same trouble here in locating herring spawn as there is in the North Sea. In fact there is no trouble at all. The spring tide rise is up to 16 feet or more. At or near high tide a school of herring passes into a Bay or into shallow water along the shore and there the females move in and out among the seaweed or eel grass, depositing the eggs as they rub against these solid objects. There the eggs adhere not only to the seaweed but to some extent to one another. In the meantime the males extrude the milt in such abundance that when it mixes with the water, the water becomes almost perfectly opaque, of a light greenish-white color. Before the tide goes down the eggs are practically all fertilised and at low tide—sometimes even at half-tide—are exposed in such large quantities that no one going near could fail to see them. The ripple caused by the fish in the water,—although this may be seen at any time when a school of herring is passing—the peculiar opacity of the water, the flocks of gulls that follow the progress of the school, the masses of eggs exposed later, inconceivably numerous, with hordes of ducks doing their best to reduce the number, each and all give unmistakeable evidence as to the locality where spawning takes place.

Although the eggs are out of the water for four or five hours at a stretch they do not seem to suffer. The bladder wrack or eel grass might retain a certain amount of moisture, but the eggs are often found attached to the bare rock, and here the moisture cannot be retained.

To see the thoroughness with which the milt is mixed with the water one wonders if it could be possible if any eggs could escape contact with some of it, but later, when one sees the spawn exposed, so many eggs in so small a space and so much space occupied, one can scarcely realise, even after seeing the method of distributing the milt, that provision could be sufficiently thorough to ensure the fertilization of every egg. The egg is so transparent that the dark eyes of the embryo, shortly before hatching, are very conspicuous, hence a glance is all that is neces-

sary to see if the egg is fertile. In mass the bad eggs are much lighter in color than are the fertile eggs. The eggs are deposited in a strip averaging from two to four rods wide near low tide, but above it at spring tide. It can be stated from personal observation that it is possible to walk for a quarter of a mile or more along such a strip without finding a single mass of bad eggs, although a mass covering a few square inches might be found occasionally. Taking into consideration that in many instances ten million eggs to the square foot would be a low estimate, the thoroughness of the fertilisation process may receive its proper appreciation. It is quite possible that the number of individual bad eggs in the smaller masses may bear a smaller ratio to the total number in the mass than the small masses of bad eggs bear to the number of such small masses in a large area. The evidence points that way. On a piece of eel grass 6 inches long there may be 300,000 eggs. The closest scrutiny will fail to reveal a single bad egg in the whole mass. Out of every egg in the mass, two bright, dark eyes shine forth, and as one looks at them with a lens every little herring will roll over in his shell to show that there is activity behind the dark eyes. Such an observation has been repeated over and over again with the same result almost invariably. Unless the eggs are laid too close to the surface so that the water subsides before they are fertilised or unless they are covered up in some quiet spot immediately after deposition, their fertilisation is practically a certainty.

Spawn may be deposited in an area of this nature practically uninterrupted for 15 miles or more within a period of three or four days, which would indicate that it all comes from the same local race of herring. After the ducks have had their share and the various shore and shallow water fish have had their quota and other enemies have helped themselves, it is quite probable that there would still be left on an average as many as a million to the square foot to hatch out. At such a rate the whole of such an area as that above mentioned would liberate about 4,000,000,000,000 young herring in one season. Such an area would be repeated several times along the coast of Vancouver Island, but to keep the figures conservative let us suppose that the fish caught by the Nanaimo fishermen came from this same race of fish. The catch for 1912-3 was approximately 25,000 tons. Taking 3.6 ounces as the average weight of a herring, there would be about 9,000 fish to the ton and in 25,000 tons there would be 225,000,000 fish. That number would be $\frac{1}{200}$ of one per cent. of the number given in the above estimate, or 1 in 20,000. It is quite evident that man's endeavor to thin out the species is thus far of little significance. When the herring come into the shallow water to spawn they can be caught with the

greatest ease and in the greatest numbers, but, as before stated, at this time they are not suitable for eating fresh, for dry salting, pickling or smoking. So unsuitable are they that any caught at this time and put on the market are apt to ruin the market for good fish. If, then, the fish are carefully protected during the spawning period, there seems to be no reason to believe that there would be danger of over fishing even if the amount caught was increased to many times the present amount. Furthermore, if all the fish shipped were in good condition, there would be little likelihood of a glutted market, even if the supply were greatly increased.

With the assistance of Mr. H. McIndoo, Fisheries Overseer, we were able to get a good idea of the times and places where spawning took place during the spring of this year (1914). The information thus obtained tends to confirm the opinion that there are different schools or races corresponding to the different localities where fish are caught in quantity during the season. Indians reported the first spawn of the season from Yellow Point on Feb. 20. No spawn was received from that locality, but doubtless the report was correct. On Feb. 26 and 27 there was an abundance of spawn deposited around Breakwater Island, through Gabriola Pass and the north shore of Pylades Channel between Gabriola Pass and False Narrows. On March 2 there was strong evidence of milt at the southeast end of Northumberland Channel in the neighborhood of Percy Anchorage, but this must have been due either to the presence of some coming through False Narrows with the current or to the fact that large hauls of fish were being made near by in the Channel and the rough handling caused a certain amount to be dehisced. This is often noticeable near where fish are being taken out of a seine. At any rate careful examination later failed to reveal any spawn in the channel. On March 9, Pilot Bay at the north end of Gabriola Island was filled with milt, and spawn was deposited in large quantities. From Pilot Bay eastward to Berry Point—the northeastern point of the island—spawning took place during the two following days. The northeast coast of Gabriola Island from Berry Point to the Flat Top Islands was visited March 12 and 13, continuing on the east side of the Island until March 17. In the meantime spawning was reported from Big Qualicum on March 8 and from the entrance of Nanoose Bay for three or four miles eastward on March 10. Mr. McIndoo found herring spawning at Ganges Harbor, Saltspring Island, on March 20, but this locality is so far away from this district where close observations were made that it can scarcely be included in any generalisation. Within the district we have quite complete data except for Cowichan Gap and the neighboring portion of Valdez Island, from which we have no records.

The spawning areas agree very well with the areas in which the herring appear in numbers earlier in the season. It would seem that one race spawned in Kulleet Bay (Chemainus Bay) from Yellow Point South. One should infer that another race spawned at Cowichan Gap, but we have no record of this. Another race spawned from Breakwater Island, through Gabriola Pass to Pylades Channel, one to the north and east of Gabriola Island and one from Qualicum to Nanoose Bay and a little farther eastward. All of these places were fished extensively with the exception of the north and east of Gabriola Island, where the eastern and southeastern storms of the winter season make fishing a troublesome occupation. Apart from these localities, extensive fishing was done in Northumberland Channel along the shore southeast from Jack Point. This race was fished until March 2, when large hauls were made in the channel just off the entrance to Dodds Narrows. These fish apparently passed through Dodds Narrows, as they appeared in large numbers on the Mudge Island shore and in the neighborhood of Round Island on March 5, but there was no sign of spawning here. They must have gone on the southward, but we have no record as to where they spawned, although spawning must have taken place soon afterwards, since, as has been previously noted, some of them were spawning in the seine on March 2.

After spawning the herring pass out into deeper water, probably not so very far away, as they make occasional visits into shallow water during the remainder of the year. How common these visits are it is impossible to say, as there has been little observation made in that regard. Evidently there are inducements for such migrations other than the necessity of finding suitable spawning grounds. It would be useless to present any conclusions concerning migration, however, until these conclusions are backed by a greater amount of evidence. It might be noted, though, that the herring have not the same trouble to get into deep water here as they have in the North Sea, since a depth of 150 fathoms or even 200 may be reached in the Strait without going far from the shore.

EMBRYOLOGY AND LARVAL DEVELOPMENT

In the mature herring just before spawning the milt and roe make up a very noticeable proportion of the whole weight. The largest male gonad examined weighed 22.7 grams, and as the fish weighed 158 grams, the two gonads made up over 28 per cent. of the weight; the largest female gonad weighed 18.6 grams, the fish 151.5 grams, 24 per cent. of the total weight. Although the younger and smaller fish do

not have as large gonads as the older and larger, the proportion to the whole weight seems to vary within a comparatively narrow range.

The eggs when ripe are 1.4 to 1.6 mm. in diameter and in weight run from 900 to 1000 to the gram weight of the ovary. In the female in which the single ovary weighed 18.6 grams there were approximately 35,000 eggs, but this size is exceptional, and in all probability there are few cases in which there are more than 30,000 even in the older fish, while in the younger a very much smaller number is found. In a single ovary there were 14,165 eggs—making 28,330 to the fish—by actual count, while in a smaller fish there were 9,489 eggs in one ovary or 18,978 eggs to the fish. The yolk fills a large portion of the egg membrane, and there are no oil globules present.

The development of the embryo in the egg is easily studied, as, not only is the membrane transparent so that the embryo and the yolk may be seen without difficulty, but it is also very tough so that the eggs will stand handling without causing harm to the embryo. The spawn from a ripe female may be squeezed out into a dish containing fresh sea water into which sufficient milt is put at the same time. The eggs adhere to the bottom of the dish, hence the water can be changed on them readily—twice a day being sufficient—so that little care is required to get the development to take place as successfully as if it were in the sea itself and therefore as satisfactorily as could be desired. It is possible to get all but the earliest stages readily by getting the seaweed at the spawning ground from time to time and keeping it fresh until the next lot is obtained. Unless new material is obtained often, this does not prove so satisfactory as hatching the eggs out in a dish with no seaweed in it, as when the seaweed is torn from the rocks it decays quickly and apparently poisons the water as the embryos, particularly if they are nearly hatched out, die off rapidly. As the spawn in the natural condition is subject to a variety of temperatures on account of being exposed directly to the sun while the tide is out, a constant temperature is not necessary when hatching eggs under observation. If the temperature is kept high, development takes place more rapidly within comparatively narrow limits, but there is a higher mortality. The best results are obtained when the temperature is kept much the same as the temperature of the sea water, which at that time is between 45° and 50° F., at which temperature, with other conditions satisfactory, there should be almost no loss. The rate of development considered in the following account corresponds to that which takes place at such a temperature.

Very soon after the ovum is shed the spermatozoon enters and fertilisation takes place. In less than two hours the first furrow in the

germinal disc is distinctly visible, and in less than half an hour more the first division is completely through the disc. In three hours division has again taken place, from which times it proceeds regularly until by the end of 8 hours the mass has arrived at approximately the 32-celled stage. From this on the number of cells increases rapidly, so much so that at the end of 12 hours almost one-fourth of the surface of the yolk is covered with the cellular disc, which is not very distinct from the yolk at its margin. In 24 hours the margin of the disc is more distinct and is showing somewhat thicker towards the centre, the boundary between the cell-mass and the yolk below being discernible in a side view. In 36 hours a distinct ridge is noticeable extending from edge to edge of the cell-mass which now covers about half of the yolk. This gradually increases in length as the mass extends over the yolk, but shows no definite thickening at any one part until after the 60th hour, although it thins out at the ends. By this time it has reached fully three-fourths of the way around the yolk. Soon after this the end, which later becomes the head, begins to thicken and become rounded off so that by the end of the third day the ridge begins to take a definite shape. During the next 12 hours much change takes place. The head becomes well defined with the eye showing, the brain and spinal cord are differentiated and several somites make their appearance, but the tail is still indistinct. The embryo reaches nearly nine-tenths of the distance around the yolk. At the end of four days the tail has become differentiated, the somites have become quite numerous, while the head is still further developed. In $4\frac{1}{2}$ days the ear has made its appearance, some indication of a heart is present, and the division into somites has taken place pretty well throughout the length of the body. The embryo has increased in length so that the tail now touches the tip of the nose, a small portion of the tip being free from the yolk. During the fifth day the head and a large portion of the tail becomes free from the yolk and the body is twisted slightly so that the tip of the tail goes past the head. The heart takes more definite shape and can be seen to beat. By the end of the fifth day the embryo itself can move about and from that time on shows considerable activity in rolling about in the limited space at its disposal. From the time that bodily movement first takes place until the embryo is hatched out the change is very gradual, consisting largely of the growth and development of the organs already present. No definite time can be given for the appearance of other organs, as the rate of growth differs materially in different cases, with a corresponding difference in time for hatching out. Under normal conditions the shortest time required for hatching was $12\frac{1}{2}$ days and the longest 22 days. Much greater numbers come out in from 14 to

16 days than during any other period, although in one case in a mass of 156 eggs examined, after 18 days 80 of them still contained embryos.

Before the hatching period, the median fin extends from the back of the head in a continuous line around the posterior end of the body and along the ventral surface forward to the yolk sac except where it is interrupted by the anal opening; the pectoral fins are developed also. The brain takes on much the structure of the adult brain, with the neural connection to eyes and ears; the nasal pits develop rather late. The heart becomes two-chambered but hangs rather loosely in the cavity in front of the yolk sac. The gill-slits make their appearance and the jaws are formed. The whole body remains transparent with the exception of a few small, irregular black spots along the course of the alimentary tract.

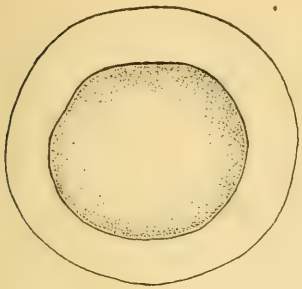
When hatched out the young herring is about 7 mm. in length and .75 mm. in depth including the fins, with a yolk-sac 1 mm. in length. The pectoral fins stand out quite prominently, but they seem to be but little used until the yolk is almost absorbed. In the newly-hatched salmon these fins are kept in rapid movement, apparently to assist in the aeration of the water, but in the herring they appear to have no such function in the early stages at any rate. The mouth is open, but the head is curved so that the mouth appears on the under side rather than at the anterior end. The gill slits are open, but as yet there are no cartilaginous supports for the arches. The alimentary tract is a tube of almost uniform size and appearance passing without convolution from the mouth to the anal opening, which is situated well towards the posterior end of the body. The liver is represented only by a couple of tubules running for some distance parallel to the alimentary tract. The kidneys are present, although they do not show much development, but the ducts can be traced readily until they join and pass out just behind the anal opening in the same papilla. There is no sign of any vertebral skeleton forming around the notochord, but this has become extensively vacuolated, so much so, that except in sagittal sections scarcely anything can be seen but the walls. The muscle segments, however, are distinctly developed, showing the regular fibrillar structure. The nasal pits are so near the undivided cerebrum that there seems to be scarcely any olfactory tracts, but the optic and the auditory nerves are well developed. The structure of the eye is practically the same as in the older forms, and in the auditory capsule the otolith, which is almost circular in cross section, is present. The optic lobes and the cerebellum are quite well developed. There is evidence of a pituitary body but none of a pineal body. The heart is not yet folded

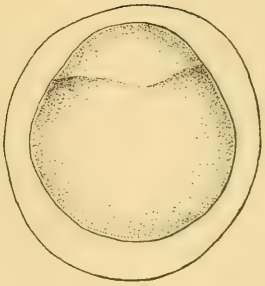
on itself, but passes back from near the symphysis of the lower jaw without showing an appreciable difference in size in its various parts.

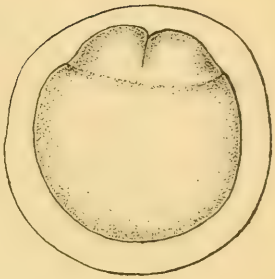
After the embryo has hatched out there is enough yolk remaining to last it about six days. During this time the principal changes that take place have to do with the digestion and the circulation, since a preparation must be made for active feeding instead of living by absorption of food material from the yolk. The nervous system has not changed a great deal, although the pineal body is now evident. The nasal pits are relatively larger than in the younger specimens. The heart is now doubled over and shows more of a difference in the chambers. The cartilaginous skeleton has begun to develop. The basis cranii appears as a united plate forward, but farther back it separates, appearing on both sides of the pituitary body, back of which it is again united below the anterior end of the notochord. Lateral projections grow up from this base so that for a little distance the notochord is almost surrounded by cartilage. At the posterior end it supports the palatoquadrate cartilage, which is well developed, as is also Meckel's cartilage in the lower jaw. Each of the gill arches is supported by a cartilaginous rod. Except at the anterior end there is no indication of the skeletal structure appearing to encroach on the notochord; scarcely any change is noticeable in it from the time of hatching. The only other skeletal portion appearing is in the pectoral girdle, where there is a well developed cartilage on each side, but these do not come very near together in the middle line. There is as yet no indication of a pelvic girdle or pelvic fins. The mouth now opens to the full width and the lower jaw articulates freely. In the digestive tract there is now a distinct enlargement for the stomach, the walls of which are already glandular. The intestine is of uniform appearance and passes as a straight tube to the anal opening. The liver shows the greatest development of any of the organs, as now it has become a solid mass of relatively large size, showing already a division into lobes. I have not been able to make out any sign of a pancreas, although in other fish—the blue cod, *Ophiodon elongatus*, for example—it becomes quite definitely established some time before the yolk is all absorbed or even before the embryo is hatched out. The kidney and its ducts show little change.

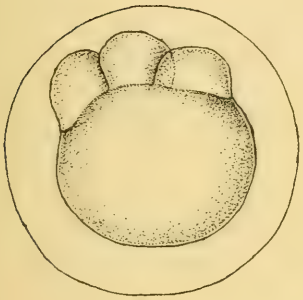
From the time the yolk is absorbed it has not been possible yet to follow continuously the process of growth. After a couple of weeks there is a gap until the fish is about 6½ months old on Oct. 9th. By this time the average length is about 5.2 cm. and the weight 1.5 grams. The scales are already well started. On Feb. 16th they have reached a length of 6.3 cm., April 4th, 6.5 to 7.0 cm. and on May 16th (14 months), 7.6 cm.

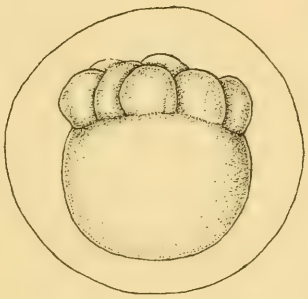
The discussion of the appearance of the scale markings as an indication of age will not be taken up at present except to say that the areas of slow growth corresponding to the winter seasons are not so definitely marked as in the salmon scales. Since in the case of the salmon there is so much difference of opinion as to age, it would be premature to make any statements regarding the herring until all conclusions receive extensive confirmation.

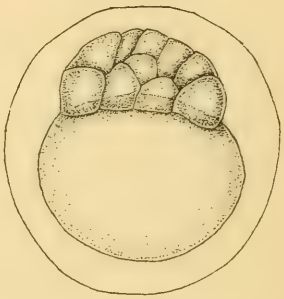

1

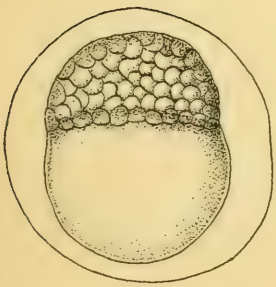

2

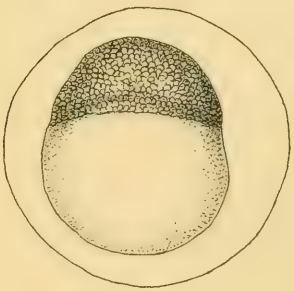

3

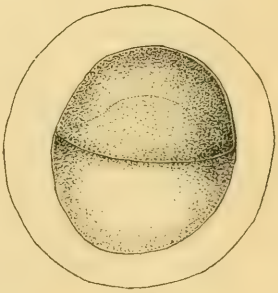

4

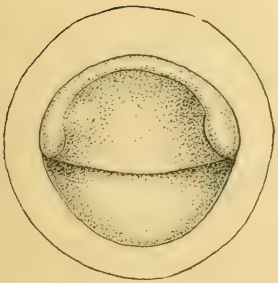

5

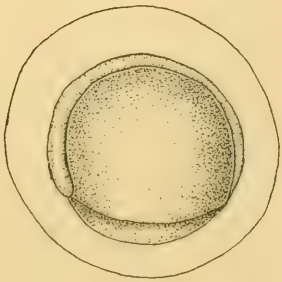

6

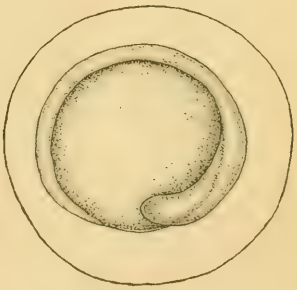

7


8

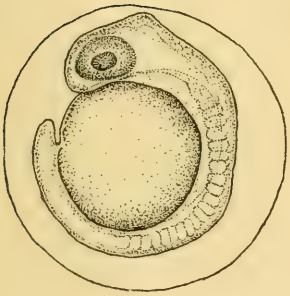

9


10

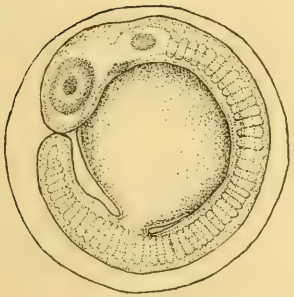

11


12

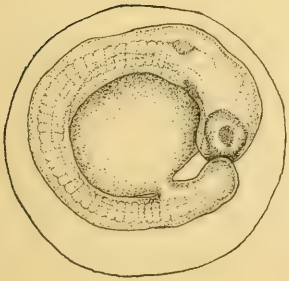
13



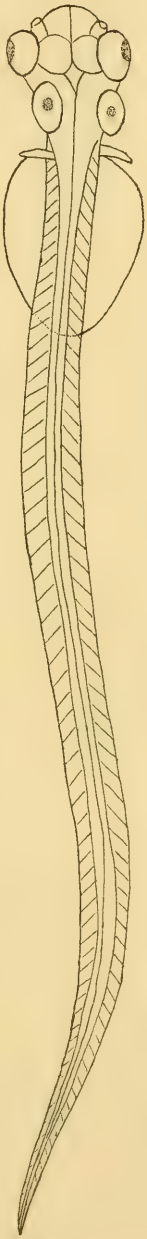
14



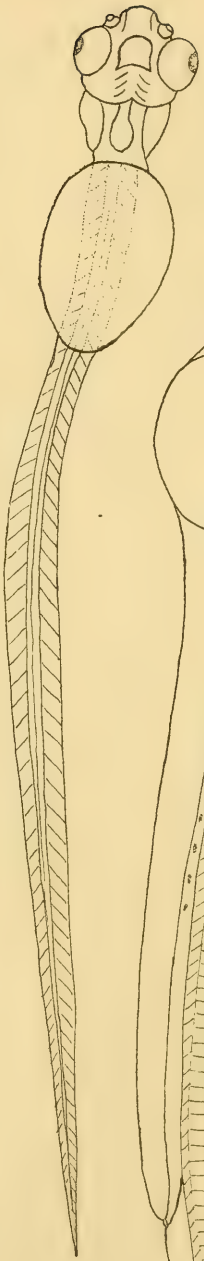
15



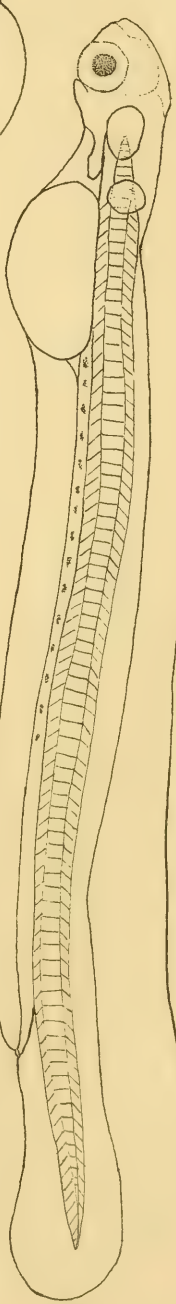
16



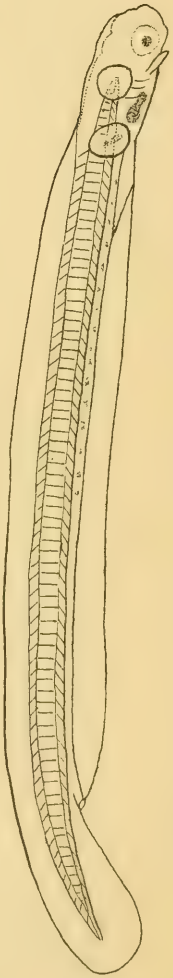
17



18



19



20

ICHTHYOLOGICAL NOTES ON:

I. *OPHIODON ELONGATUS* GIRARD;
II. *ONCORHYNCHUS KETA* WALBAUM;
III. THE DIAGNOSIS OF FISH BY MEANS OF THE SCALES;
IV. *MALLOTUS VILLOSUS* MÜLLER.

By C. McLean Fraser, Ph.D.,
Curator of the Marine Biological Station, Nanaimo, B.C.

I. *OPHIODON ELONGATUS* GIRARD.

Plate X, figs. 21-25

Fishes in general pay little attention to the well-being of their progeny. In oviparous forms the eggs are shed, provision is made for fertilisation and that is the end of it as far as the parent is concerned,

Among the exceptions to the general rule is *Ophiodon elongatus*. commonly known as the Blue or Green Cod. The eggs of this species are very adhesive so that after they are shed they are collected into a large mass which becomes attached to a rock, usually in a crevice or some other unevenness, a short distance below low water or occasionally in such a position that they may be exposed during a low spring tide. Over the mass the parent fish keeps guard so well that no intruder has much chance of meddling. In no case have I found the female engaged in this protective duty, but if she does not take any part, the male must have a weary vigil, as the period of incubation is about two months.

In the first instance my attention was directed rather forcibly to this characteristic of the Blue Cod. While collecting at low tide near the Biological Station, Departure Bay, I saw a mass of eggs under a rock about a foot and a half below the surface of the water. Wishing to examine some of them I managed to force off a small bunch with the blade of an oar—they stick so solidly together that this is not an easy matter—immediately after which I put down a dip net to catch them before they would sink to the bottom and was somewhat surprised with a sudden jerk that almost took the dip net out of my hand. A little later I discovered that the jerk came from a large cod that appeared from under the rock to resent the intrusion. When I thought of the sharp teeth of *Ophiodon* I was much better satisfied that the net rather than my hand received the force of the attack. The satisfaction was by no means decreased when further experiment showed how savagely he could attack starfish, nudibranchs, etc., that were lowered

to test his watchfulness. Since that time the dip net has received many a jerk for a similar reason when it has been poked among the rocks in collecting. When the tide is low and the surface of the water is smooth, it is an easy matter in certain localities to see several of these fish on duty, as the opaque whiteness of the mass of eggs makes discovery an easy matter.

In the vicinity of Nanaimo spawning takes place during the latter part of January or early in February. The eggs, about 2.8 mm. in diameter, differ from the eggs of many other species in that they are so opaque that nothing can be seen of the development of the embryo with a lens or microscope, hence the early stages can be studied only by sectioning. I have not made such studies, because I considered it would be of little use to do so unless the earliest stages could be studied hour by hour, and in no case have I been certain within a day when the eggs were fertilized. Moreover, I have not had the same success in hatching out blue cod eggs in the laboratory that I have had with the eggs of other species. They seem to go bad very easily.

Although I have not got these earliest stages, I have been fortunate enough to get some embryos just hatched out. When the eyes are developed they show as dark spots in the eggs. After development had proceeded thus far I examined the eggs at intervals and thus managed to get a number hatched out shortly after they were brought into the laboratory. This was on March 25th. The newly-hatched embryo or alevin as it may now be called, is 11-12 mm. in length, with development well advanced. A certain amount of color is produced by a number of fine dark spots on the head, bands of them on each side of the dorsal fin and a less pronounced band below the lateral line. There is no break in the continuity of the median fin except at the anal opening, but there is little of it anterior to that opening. The pectoral fins are present, but they are not well developed. They do not seem to be used at all to assist respiration. There is no sign of the ventral fins.

There is not much sign of skeletal tissues. A broad plate of cartilage extends for some distance under the cerebrum, but it soon narrows and disappears before the optic chiasma is reached. At the anterior end of the notochord it again appears, forming an irregular plate of considerable size. A portion of it extends out to form part of the capsule of the ear and posteriorly it grows up around each side of the medulla almost to the mid-dorsal line, but this lasts only for a very short distance. Laterally it connects up with the articular portion of the mandible, which is slightly developed. There is a cartilaginous rod in each gill arch. The skeleton of the pectoral girdle is but slightly developed, and this only in the part some distance from the middle line, in the fin

itself. The notochord is relatively rather small, and at this period is entirely vacuolated.

The nervous system is well developed. In the brain the cerebral hemispheres are almost distinct; the optic lobes are large, with the cavity separating as it passes backward; the epiphysis and the pineal body show up well; the hypophysis and the saccus vasculosus are relatively of large size, and the cranial nerves show distinctly. Judging from their appearance, the sense organs must be almost as well suited for action as they are in the adult. The nasal pits are quite deep and possess a large sensory surface, the eye has the structural characteristics and the nerve supply of the adult, while the ear is relatively of large size, and is extensively chambered with the ampullæ showing distinctly.

Although much of the yolk—there is an oil globule present—remains unabsorbed, the digestive system is apparently of high enough development to look after food taken directly from the sea. At any rate in certain other fishes there is not so high a development when the yolk is all absorbed. The mouth is of large size, with the posterior portion of the cavity in direct connection with the outside through the large gill-clefts. The digestive tube does not vary much in size throughout, but it is bent on itself to form a loop of considerable length. The anal opening is quite far forward, a short distance posterior to the yolk-sac. The lobed liver is of large size with well developed hepatic tissue. The pancreas shows up distinctly.

The excretory organs must be strongly functional, as the kidneys have got much beyond the single tubule stage and the ducts are relatively of large size.

In the circulatory system, the heart has become quite muscular, with the chambers and general shape much the same as in the adult. The aorta with its branches through the gill arches can be traced easily, and many other of the large arteries and veins have become distinct.

Taking it as a whole the young *Ophiodon*, as it emerges from the egg, is in good condition to look after itself, although, as in the majority of young fishes, it will have enemies in plenty, enough to require the use of all its powers, no matter how fully they are developed.

II. *ONCORHYNCHUS KETA* WALBAUM:

"DOG SALMON"

Plate X, figs. 26-29

One of the characteristic sights in the shallow waters of Departure Bay near the Biological Station, during the spring months, is the continuous bubbling of the water due to the presence of myriads of young

dog salmon, *Oncorhynchus keta*. This year they appeared as early as March 4th, when a few straggling schools of from 8 or 10 to 20 or 30 appeared in the shallow water near the shore. These were 30-35 mm. long, and several retained part of the yolk, although already they had the characteristic parr-marks in the majority of cases. Some of them, even when much older than this, or perhaps rather when they are much older, have no sign of the bars, so that they look very much like humpbacks. It seems scarcely possible that they are anything but dog salmon, as they are found in the same school with the barred forms, although at certain times they seem to predominate.

After watching these fry for some time, the wonder that they grow so rapidly after they reach sea water gradually disappears, as it would be hard to imagine a more active mass of condensed hunger than each of these appears to be. Watch them at any time during the day and the restless movement goes on. A snap is made at a desirable morsel here and another there, with no intermission of any length. At night when other sounds are stilled, the continuous jumping and splashing makes a ripple like that of a brook bubbling over a pebbly bed, so that it can be heard distinctly many rods away from the shore. Looking down over the water one sees them pass on in their illumined way as they disturb the various phosphorescent forms, some of which become phosphorescent no more. Occasionally when a large fish comes up with a splash to devour some of them, those fortunate enough to escape the cruel jaws, make such a speedy departure from the spot that the phosphorescence becomes more noticeable, looking like a meteoric shower in miniature.

Catch them when you will, their stomachs are gorged with food, and one would think that their digestive systems would have to work overtime to get everything assimilated. They are not particular as to their diet. Apparently anything that can be swallowed goes. If one edible species is abundant that serves very well; if there is great variety that seems to do just as well. On one occasion I found them eating nothing but dipterous insects, at another nothing but barnacle larvæ, at another nothing but appendicularia. At one time they were filled with cladocera and mollusc eggs; a few days later this was changed to amphipods and mollusc eggs. The greatest variety found at any one time appeared in two salmon caught on June 12th, 1913. In these two there were cladocera, barnacle larvæ, copepods, crustacean sloughs and mollusc eggs in abundance, a dipterous insect, a crab larva and a young mussel.

I know of no reason for their being here in such numbers unless there is an especially abundant supply of food for them. This may be so, as the waters eddy into the Bay a good deal and many of the smaller

forms are apt to be brought in with the currents. Although some of them linger around the mouth of the stream near by, others remain some distance away where the water is as salt as it is out in the open, hence it seems that salinity can have nothing to do with it. They are not hatched out very near by. So far as I am aware none are hatched nearer than the Nanaimo River, the mouth of which is four miles distant. That is quite a distance for the young salmon to come through the salt water before they are out of the alevin stage.

When the yolk disappears there is no indication of any scales in the skin. About the middle of May when the fry are 40-45 mm. long, the scale makes its first appearance. It is round or oval, 0.14 to 0.2 mm. in diameter, smooth and without rings. It is the nucleus of the large scale. In a week or two the first ring appears, soon followed by others, until by the end of June, when the fry disappears from this locality, there are 8 or 9 rings surrounding the central nucleus.

Occasionally a few larger fish appear with the small ones, but I have not been able to obtain any of them. They are three or four inches long, and in all probability are dog salmon that have remained in the fresh water until the second spring instead of coming down the first spring. If one is to judge from the number that appear here, the proportion of second year fish is so low as to be almost negligible.

III. DIAGNOSIS OF FISHES BY MEANS OF THE SCALES

Plate X, figs. 30-35

A system of identification of fishes by means of their scales has been advanced by Prof. T. D. A. Cockerell, but so far the system does not seem to have met with very great favor. Yet it is quite possible that the scale can be relied upon for identification purposes at least as fully as any other single characteristic if not as fully as all others combined. Since it has been discovered that the appearance of the scales may serve as a reliable indication of the age of the fish, the study of fish scales has become almost a science in itself, and there is no doubt but that it will add materially to the means of attacking the many problems connected with the life history. Two cases of personal interest may be quoted to show the value of the study of the scales in diagnosis.

For some time after taking a special interest in the life-history of the herring, I knew nothing of the development between the time when the yolk was just absorbed and the time when the young fish was 6 cm. or over in length and had taken on the general appearance of the mature herring. On June 6th, 1913, there were numerous young fish, 35-40 mm. long, around the Government wharf on Gabriola Island. By June 12th

they were plentiful around the station wharf and at other points in the neighborhood, like other young fish, with apparently ravenous appetites, feeding day and night on anything that could be swallowed. On the night of June 26th they were so numerous and were making so much disturbance in the water that I went out about 10 p.m. with a plankton net to find out what formed the food supply. There was scarcely anything but rotifers in the catch, but these were there in plenty. The stomachs of the fish were filled up with these. (Earlier in the evening the dog salmon fry were feeding almost entirely on Diptera.)

These were undoubtedly Clupeids, but were so unlike the herring of 6 or 7 cm. in some respects that I could not feel sure as to their identity. Anyone who has tried to diagnose very young fish from the descriptions given in the manuals, no matter how satisfactory they may be for mature fish, will know what a difficult job it is. The fry is often so unlike the adult in many particulars. One of the common differences occurs in a characteristic on which much stress is laid as a means of identification, *i.e.*, in the number of fin rays in the various fins. In comparing the fry of a number of species with the adults in this respect the fin rays have been found to be more numerous in the fry, the reason apparently being that from 2 to 4 of the anterior rays coalesce to form a stiffer support for the forward portion of the fin. The number of fin-rays, which one might suppose would provide one of the easiest means of identification in the fry, can in no sense be depended upon. This was one of the difficulties here. Other diagnostic features, such as the absence or presence of teeth on the vomer, can scarcely be made out with certainty, as such accessories, although present in the adult, may not yet be developed in the fry. The color cannot be depended on, for the greatest variation occurs. In this case the fish in question were much lighter in color than the older herring, and had not the metallic sheen. There was nothing in all this to prove conclusively that these fish were herring and not some other species of the Clupeid family, *Clupanodon cæruleus*, for instance, as that is found in the vicinity also.

Young as the fry were, the scales were already formed and developed sufficiently to show something of the permanent structure. The scales of the adult herring and pilchard bear considerable resemblance, although they are markedly different. The pilchard scale is much larger and has characteristic scars passing in obliquely from the margin at the sides. Since the scales of the fry were very small and corresponded to only a small portion of the adult scale, the difference in size of the adult scale did not help in the diagnosis, and as the characteristic scars of the pilchard do not pass all the way to the nucleus, it was possible that although

these scars were not present, it might be that the scale had not grown enough for the beginnings to be included. An examination of several scales of each species showed that even in the central area there was a constant difference. The transverse lines are closer together in the pilchard and they show a difference in the nature of the interruption towards the median line. The scales of the fry correspond to the central portion of the herring scale rather than that of the pilchard and the question of the species was definitely settled. Three camera lucida drawings will indicate the comparison. The first is of the complete fry scale, the second of a central portion of the adult herring scale of the some size as the previous, and the third of a similar portion of an adult pilchard scale.

Later a more complete series of the young herring was obtained, both of older and younger specimens, and it seems as though the change to the appearance of the adult takes place very soon after the stage that provided the problem above indicated.

The other instance shows the value in a somewhat different direction. On June 8th, 1914, a perch or surf-fish was caught near the Station and brought in. On examination, Dr. Willey found that while in general it answered very well to the description of the white surf-fish, *Phanerodon furcatus*, yet it differed very materially in some particulars. The dorsal fin provided the most noticeable of these. In the typical *Phanerodon*, according to Jordan and Evermann, the spines are all of considerable length, gradually increasing from before backward until the last spine is often higher than the soft rays, while in the specimen the spines were all low, the last one being less than half of the length of the soft ray, exactly corresponding to the dorsal fin of a closely allied species, *Tæniotoca lateralis*. Specimens of these two species were at hand to emphasize these points.

An examination of the scales was resorted to, in order to get further light on the question. The *Phanerodon* used in comparison was a much younger and smaller specimen but the *Tæniotoca* was of full size. The scales showed the close relationship between the different species, but it was no trouble to see the marked resemblance between the scale of the young *Phanerodon* and the corresponding portion of the scale of the specimen in hand and the dissimilarity between it and that of *Tæniotoca*. (See figures 30, 31 and 32). Taking this into consideration, it was impossible to conclude otherwise than that the specimen belonged to the species *Phanerodon furcatus*.

IV. *MALLOTUS VILLOSUS* MÜLLER:

"THE CAPELIN".

Plate X, figs. 36-39.

The run of the capelin is looked forward to each year by a great number of people, who consider them quite a delicacy. They visit Departure Bay about the first of October and remain a week or ten days. The individuals deposit the spawn or milt in the sand at the water's edge, many of them being left high and dry as the wave recedes. If the surf is at all high they may be thrown up for some distance on the sand, particularly when they are chased by the arch enemy of all small fish, the dogfish. The eggs, 1.0 to 1.1 mm. in diameter, hatch out in the sand in about 30 days and the fry are carried out by the waves.

From the scale point of view the capelin is of interest on account of the effect produced by the special scales that form longitudinal bands, two above the lateral line and two below it. In the males in particular these project so prominently that distinct ridges are formed and the fish appears quadrangular. The fish themselves are small, averaging about 11 cm. in length and weighing 11 grams. The scales are correspondingly small, although it cannot be laid down as a rule that small fish have small scales and large fish large scales.

The ordinary scales are circular or oval, less than 1 mm. in diameter, with an elongated nucleus reaching almost across the scale. Around this nucleus are arranged from 8 to 12 rings. The scales that form the longitudinal bands vary much, but follow more or less two pronounced types. The one of these has an oval scale as a basis, from the margin of which extends a spike-like projection, in length about twice as great as the width of the scale. The other has not the circular base. It is about half as broad as the ordinary scale, but keeps pretty well to that size throughout except that it comes to a blunt point at its distal end. It varies in length and may be much longer than the other mentioned. In both of these the rings appear in practically the same number as in the regular scales, but they are not so complete or distinct as in the others, but simply pass from one side of the scale to the other.

If the scale starts to grow in the capelin as soon as it does in other fish, and I see no reason why it should not, this would indicate that they are but one year old when they spawn and unless larger individuals are found elsewhere, that they perish after spawning. There is some indication of this in the fact that in the latter part of the run many of them are battered up and diseased, having somewhat the same appearance as the various species of Pacific salmon after they have spawned and are dying in the streams.

EXPLANATION OF PLATES

Drawings by Clara A. Fraser

PLATE VIII.

Fig. 1—Unincubated egg of Pacific herring, *Clupea pallasii.*
Fig. 2—Egg after 1½ hours.
Fig. 3—Egg after 2 hours.
Fig. 4—Egg after 3 hours.
Fig. 5—Egg after 4 hours.
Fig. 6—Egg after 8 hours.
Fig. 7—Egg after 12 hours.
Fig. 8—Egg after 24 hours.
Fig. 9—Egg after 36 hours.
Fig. 10—Egg after 48 hours.
Fig. 11—Egg after 60 hours.
Fig. 12—Egg after 72 hours.

Note.—Magnification in Figs. 1-12 24 diameters.

PLATE IX.

Fig. 13—Herring egg after 84 hours' incubation.
Fig. 14—Egg after 96 hours.
Fig. 15—Egg after 108 hours.
Fig. 16—Egg after 120 hours.
Fig. 17—Newly-hatched alevin, dorsal view.
Fig. 18—Newly-hatched alevin, ventral view.
Fig. 19—Newly-hatched alevin, side view.
Fig. 20—Fry with yolk all absorbed.

Note.—Figs. 13-19 magnified 24 diameters, Fig. 20 magnified 12 diameters.

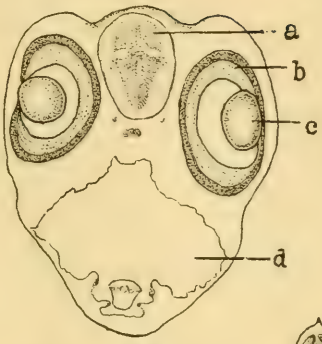
PLATE X.

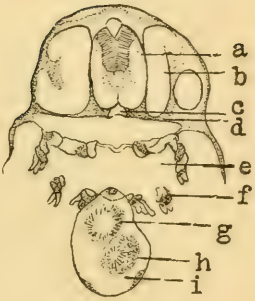
Fig. 21—*Ophiodon elongatus.* Newly-hatched alevin. ×15
Fig. 22—Cross section of the head in the region of the eyes. ×24. *a*, brain; *b*, eye; *c*, lens; *d*, mouth.
Fig. 23—Cross section of the head through the auditory organs. ×24. *a*, brain; *b*, cavity of auditory organ; *c*, dorsal aorta; *d*, basal plate; *e*, mouth cavity; *f*, gill arch; *g*, auricle; *h*, ventricle; *i*, pericardial cavity.
Fig. 24—Cross section of the body through the kidneys. ×24. *a*, spinal cord; *b*, muscle; *c*, notochord; *d*, pectoral fin; *e*, dorsal aorta; *f*, kidney; *g*, digestive tract; *h*, yolk; *i*, oil globule.
Fig. 25—Cross section of the body through the liver and pancreas. ×24. *a*, spinal cord; *b*, muscle; *c*, notocord; *d*, pancreas; *e*, digestive tract; *f*, liver; *g*, yolk; *h*, oil globule.

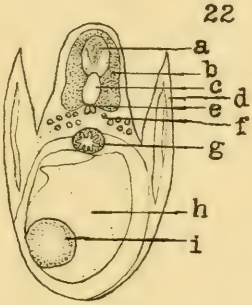
PLATE X—*Continued.*

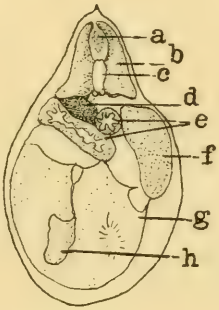
Figs. 26, 27, 28, 29—Stages in the early development of the dog salmon scale. ×24.
Fig. 30—Scale of young *Phanerodon*, showing shape, distinguishing marks and centre. ×12.
Fig. 31—Central portion of scale of doubtful specimen. ×12.
Fig. 32—Central portion of *Taniotoca* scale. ×12.
Fig. 33—Complete scale of young herring. ×24.
Fig. 34—Central portion of adult herring scale. ×24.
Fig. 35—Central portion of adult pilchard scale. ×24.
Figs. 36, 37—Ordinary scales of capelin. ×24.
Figs. 38, 39—Special capelin scales. ×24.

21

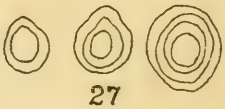

a
b
c
d
22


a
b
c
d
e
f
g
h
i
23

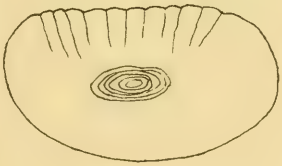

a
b
c
d
e
f
g
h
i
24

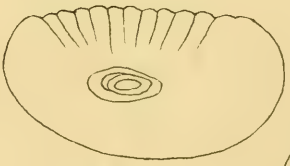

a
b
c
d
e
f
g
h
25

26

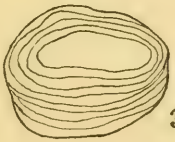

27

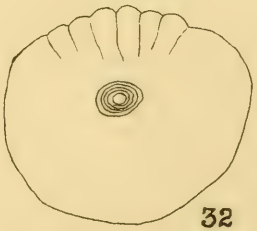
28


30

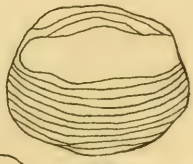

31

29


36

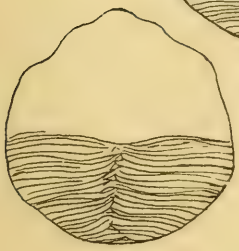

32

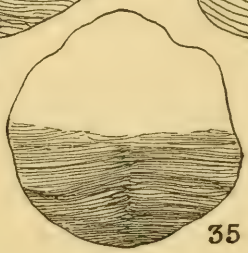
33


37

38

39




35

SUBMARINE BOATS

By COMMANDER WILLIAM HOVGAARD

Professor of Naval Design and Construction, Massachusetts Institute of Technology, Boston, Mass.

I. HISTORICAL REVIEW.

EARLY BOATS.

(*Read January 23rd, 1915*).

THE conception of submarine navigation is an old one, and submarine boats have been built and operated fairly successfully several times during the last hundred and forty years. As early as 1624 we hear of a Hollander, Dr. C. J. Drebbel, who constructed a wooden submarine boat propelled by oars. With this boat he experimented on the Thames. Submarine boats, however, did not acquire practical military importance till in this century, because not till then did the technical resources at the disposal of the inventors permit a practical solution.

During the years 1771 to 1775 an American, David Bushnell of Connecticut, constructed a submarine vessel which he called the *American Turtle*. It was built of wood and the shape was that of two tortoise shells stuck together. The boat possessed in a primitive form most of the essential features of modern types. A mine box of wood containing 150 lbs. of gunpowder was carried on the outside and was to be attached with a screw to the bottom of the enemy ship. During the War of Independence an attack was attempted against a British frigate, the *Eagle*, but the operator did not succeed in fixing the mine, which exploded harmlessly at a distance from the ship. Bushnell was the first inventor of the submarine mine. He showed, what was then considered marvellous, that gunpowder could be made to explode under water. He well deserves the title accorded to him as the "Father of Submarine Warfare".

Robert Fulton took up the ideas of Bushnell and with more means at his disposal he advanced the solution of the problem considerably. It is of interest to note that Fulton was a peace advocate, and when he devoted so much energy to the development of the submarine boat as also of the submarine mine, it was on the ground that he believed these weapons would make war on the sea impossible. Other friends of peace have had the same belief. We know now how much they have been mistaken. Fulton went to Paris in 1797 and laid his plans for a

submarine boat before the Directory, but it was not till three years later, when he offered his design to Bonaparte, who was then First Consul, that his plans were seriously considered. Bonaparte saw the possibilities of the new weapon and appointed a Committee consisting of Volney, Monge, and Laplace, who gave a favorable report. A sum of 10,000 francs was appropriated for the purpose and an experimental boat was constructed. The shell plating of this boat was of brass with iron frames. The boat was propelled by hand-driven screws. Fulton descended to a depth of 25 ft. and remained under water for more than four hours. He carried a store of compressed air in a tank for renewal of the air. He blew up a small vessel in the harbor of Brest, attaching a mine to her bottom. In spite of the relative success of the experiments, Napoleon realised that the speed, which was only two knots, was too small for military purposes, and nothing further was done.

During the Civil War in America a number of so-called "*Davids*" were built by the Confederates. Although referred to as submarine boats, they were probably most of them surface boats, going awash with very little freeboard, showing practically only a cupola above the surface. Some of them were designed for diving, but it is not known that any of them operated successfully under water. Most of the *Davids* were constructed of iron plates and some were propelled by steam-power. They were built in haste with limited resources and necessarily primitive in construction. They are of interest chiefly because they were actually employed in war and because one of them, a hand-driven boat, succeeded in blowing up a Northern ship, the *Housatonic*.

At the same time the French Government built a submarine boat, the *Plongeur*, which was launched at Rochefort in 1863. The *Plongeur* was of about 450 tons displacement, much larger than any boat built heretofore and thereafter up till a few years ago. The general shape was not unlike that of an ordinary torpedo boat, and it carried a superstructure on top in which was housed a detachable boat to be used in case of emergency. The hull was built of iron plating stiffened by frames. Ballast tanks were fitted for changing the displacement, and the depth was to be kept by two regulating cylinders which produced variations in the force of buoyancy. There were also vertical and horizontal rudders. The boat was propelled by an engine driven by compressed air, whence a very large store of compressed air at a pressure of 12 atmospheres was carried. The engine was of 80 horse-power and operated a propeller which gave the boat a speed of about 5 kts. on the surface. *Le Plongeur* went down to depths of from 30 to 40 ft., she could slide along an even bottom without difficulty, but steering in the vertical plane caused great difficulties. She was the best designed

boat up to that time, but the speed was too slow, the radius of action small, and steering in the vertical plane remained an unsolved problem. The boat, therefore, had no military value and in 1874, after ten years of experiments, the French Government abandoned the project.

THE PERIOD FROM 1880 TO 1905.

The greatest difficulty before the designers of submarine boats prior to 1880 was to find a source of power suitable for underwater propulsion. Compressed air, tried in the *Plongeur*, was probably the best available means of storing energy for that purpose, but the air reservoirs occupied too much space, whence the supply of energy that could be carried was too limited. It was, therefore, of the greatest importance for the solution of this problem when in 1880 the French scientist Faure succeeded in improving the lead accumulator, invented by Planté in 1859, by applying a layer of red lead paste as an active material to the lead plates. The accumulator so perfected afforded a means of storing energy eminently adapted for submarine boats since it was independent of the atmospheric air and, although heavy, took up relatively little space.

Another difficulty was that no weapon existed, suitable for a submarine boat. Neither the attachment of mines to the bottom of an enemy's ship, or the use of spar or towing torpedoes offered satisfactory solutions, and ramming was at least as dangerous to the submarine boat as to the enemy's ship. Another great step in advance was, therefore, made when the Whitehead torpedo appeared about the end of the "seventies". This weapon enabled the submarine boat to attack a ship from a distance without difficult and dangerous manœuvres.

At the same time there was in the "eighties" a strong development in all machinery and fittings used in the application of electric power and light, and great progress was made in the production and storage of compressed air.

Thanks to all these inventions and to the general rapid advance in all fields of engineering which was characteristic of that period, the problem of the submarine boat suddenly became capable of a practical solution. In various parts of the world designs were prepared and experimental boats were constructed, which before the end of the century led to the production of boats practically applicable in naval warfare.

In the "eighties" the author of this article commenced to study the problem* and worked out several designs of which that of a "diving boat" published in 1888† will be here briefly described in order to

**Submarine Boats*, London, 1887.

†*On Proposed Designs for Surface Boats and Diving Boats*, Institution of Naval Architects, London, 1888.

illustrate the general standpoint of the problem at that time. It was realised that ordinarily a submarine boat would travel on the surface, and that diving would only be necessary occasionally, namely when in the presence of an enemy. Hence the boat was designed essentially for work on the surface and was given a form very similar to that of a Thornycroft torpedo-boat. A large self-bailing superstructure was fitted on the top, by which a good freeboard and longitudinal stability and hence good seagoing capability were secured. The total reserve buoyancy was about 33 per cent. of the displacement in light condition, half of which was obtained by emptying internal ballast tanks, the other half was due to the self-bailing superstructure which was provided with valves that could be closed watertight. The propulsion was to take place on the surface by steam-power and in the submerged condition by electric accumulators. A combination of electric power for submarine propulsion with another distinctly different source of power for the surface secured at once the military qualities of high speed and great radius of action necessary for bringing the boat to the field of operation of the enemy, and invisibility and perfect protection by going submerged when in the presence of the enemy. The design provided for an armament of two Whitehead torpedo tubes in the bow, giving great power of attack.

The type thus proposed, where principal importance was attached to service in the surface condition, was later perfected, and boats designed on this principle are now generally referred to as "submersibles" in contradistinction to "submarines", which are designed more particularly for submerged work. The characteristics of the two types will be more fully discussed later.

During the "eighties" a Swede, Mr. T. Nordenfelt, built several boats and attained a fair measure of success. He used steam-power for propulsion both on the surface and under water, the steam when in the latter condition being derived from a store of hot water in a reservoir. The system was simple but in order to obtain an appreciable radius of action under water a large store of hot water under a high pressure had to be carried, whence much space and weight were required. Another and serious drawback was that the heat would leak away and the pressure fall in the hot water reservoir in a relatively short time. The Nordenfelt boats were manœuvred on an even keel, and horizontal propellers were used to secure immersion and to maintain the desired depth. The last Nordenfelt boat, built for the Russian Government, was $\frac{160}{250}$ts. and the speed was $\frac{14}{5}$kts.* The form was very nearly

*The upper figures in the fractions refer to the surface condition, the lower figures to the submerged condition.

ship-shaped, and the superstructure was very long. The control of the motion in the vertical plane was never satisfactorily attained in the Nordenfelt boats.

In France M. Claude Goubet experimented during the "eighties" and "nineties" with a small type of boat driven only by electricity derived from a battery of primary cells. He was entirely successful and his experience proved of great value to later designers, but the boats were too small and slow to be of military value. The French Government, therefore, rejected his boats, and in 1886 set to work to build submarine boats itself.

The first boat built by the French Government since its attempt with the *Plongeur* was the *Gymnote*, laid down in 1886, a small 30 ts. electrically-driven experimental submarine. As in the Goubet boats the power was at first derived from primary cells, but later a storage battery of iron-copper elements and finally of lead accumulators were substituted. Lead accumulators were here, it appears, used for the first time in submarine boats.

In 1889 a much larger boat, the *Gustave Zédé*, $\frac{266}{274}$ts., was laid down She was likewise driven by electricity only and was designed for high speed. The ratio of length to diameter was about 15. Great difficulties were experienced with the storage battery. On one occasion the battery was so badly damaged by short-circuiting that it had to be dismantled, whereupon larger cells of an improved type were substituted. Vertical steering proved very difficult, the boat often took excessive inclinations and hit the bottom on some occasions. Additional horizontal rudders were fitted, so that at last there were rudders both forward and aft and also amidships.

The construction of the next boat the *Morse* was suspended for a long time pending the alterations in the *Gustave Zédé* and was not completed till 1898. The *Morse* was more ship-shaped and carried an optical tube, probably of primitive construction. This was a most important addition to the outfit of the submarine boat, because if further developed it promised to solve, partly at least, one of the greatest difficulties connected with submarine navigation, viz., the complete blindness of the boat when travelling under water. It enabled a boat to approach an enemy within striking distance of the torpedo without the necessity of coming to the surface, showing at intervals only the head of the periscope a few feet above the water.

In 1899 was launched the *Narval*, $\frac{117}{202}$ts., designed by M. Laubeuf, a French naval constructor. This boat represents in an eminent degree the type referred to before as a "submersible", which term was first introduced by M. Laubeuf to distinguish between his ship-shaped boat

and the previous spindle-shaped boats built by the French Government which he called "sous-marins". The hull is double, consisting of an inner spindle-shaped "strength hull" of heavy construction, calculated to resist the maximum pressures of the water, and a light outer ship-shaped hull which completely envelops the inner. The shape of the aft-body resembles that of a Thornycroft torpedo boat. The space between the two hulls is used chiefly for water ballast, whence a very great reserve buoyancy may be obtained. It was found difficult at first to fill the tanks in a complete manner; whence shifting of air-bubbles were apt to cause violent changes in the longitudinal balance of the boat, and the vertical steering was disturbed. Also the filling of the tanks took nearly one-half hour, much too long for immersing the boat when in the presence of an enemy. These defects were afterwards remedied in the *Narval* and were avoided in later boats of this type. The *Narval* was driven by steam in the surface, where she made 12 kts. The boilers used oil-fuel. Under water she was driven by electric power and attained a speed of 8 kts. She carried four 18-in. torpedo tubes. The heat from the machinery caused considerable trouble. On the whole, however, the *Narval* proved satisfactory and was the type ship for a great number of following boats. Other types of submersibles which have later been developed, such as the Germania and the Laurenti types, are derived from the Laubeuf boats.

In the United States Mr. John P. Holland worked with great perseverance for a number of years and built several experimental boats. The first, which was very primitive, being worked by hand-power, was launched in 1878. Finally, through the agency of the Holland Torpedo Boat Company, he succeeded in producing a boat that was accepted by the United States Navy in 1899. The boat, which was named the *Holland*, was $\frac{67}{74}$ tons; it was cigar-shaped with but a small superstructure on the top and, consequently, had very little stability in the surface condition. The reason of the success of this boat was the use of a gasoline engine for surface work, combined with a storage battery for the submerged condition. Holland first tried steam-power but failed, and the gasoline motor which had just then been developed to a practicable shape was here used for the first time in submarine boats. The gasoline engine had several great advantages; it occupied relatively small space and did not produce so much heat as a boiler and steam engine; it consumed very little fuel so that a great radius of action could be obtained. The engine of the *Holland* was of 50 H.P. and gave the boat a speed of 8 kts. on the surface. The electric motor was of about the same power and drove the boat with a speed of 6 kts. under water. A novelty in this boat was the way in which diving was effected. Contrary to earlier

experimenters who held that the axis of the boat should as far as possible be kept horizontal, Holland boldly effected immersion and emersion by "porpoising", *i.e.*, by inclining the axis, sometimes to great angles, using the horizontal rudder fitted in the stern. This method of controlling the vertical motion proved satisfactory although not without danger, for it has happened that boats of the Holland type took deep involuntary dives. Holland's experiments showed the great importance of keeping the centre of gravity immovable and of compensating for all changes in buoyancy.

The Holland type was reproduced in the United States Navy in the *Adder* Class and following types and in England Vickers commenced building the A-class for the British Navy.

During the "nineties" another American Mr. Simon Lake constructed several experimental boats, and evolved a type of which the *Protector*, $\frac{136}{174}$ts., built in 1901-2, was the first representative.

The *Protector* belongs to the submersible type, having a ship-shaped superstructure and a reserve buoyancy in the light condition of about 28 per cent. of the light displacement. Diving and emersion takes place as in the *Gustave Zédé* by four horizontal rudders, the boat being always kept nearly on even keel. Mr. Lake's first idea was to produce a boat suitable for salvage operations and the like, and he for this purpose fitted wheels forward and aft hung by pivoted steel jaws fitted in pockets in the bottom and cushioned by hydraulic cylinders. These wheels enabled the boat to run along on an even bottom with a slight deficiency in buoyancy. The means of propulsion are the same as in the *Holland*.

MODERN BOATS.

The early development of submarine boats was groping and erratic, the "eighties" and "nineties" was a period of experimentation, resulting in a great variety of types, but after about the year 1900 boats entered into actual military service, with the result that an elimination of the less practicable features took place, and there followed a movement towards a unification of type. At the same time the nautical and military requirements led to a steady increase in displacement and power. Great progress was made in perfecting the various technical appliances. We shall now briefly describe recent types of boats so far as their various features have been made public.

In the British Navy the Holland type was gradually modified considerably. The ratio of length to diameter, which in the A-class was about $5\frac{1}{2}$, was much increased. Later boats were given large side structures patched on outside the spindle-shaped strength hull, the object being

probably to gain greater tank volume, greater stiffness in the surface condition, and greater safety against collision. The displacement in the E-class is $\frac{710}{820}$ts. and in the six boats of the F-class laid down in 1913 it reaches $\frac{950}{1200}$ts. and the speed is $\frac{18}{12}$kts. No data are known about later boats, but they are probably larger and more powerful.

In the United States the Electric Boat Company developed the Holland type. Boats of the M-class have a submerged displacement of 800 ts. A larger boat of about 1200 ts. displacement is to be laid down this year. The price of this boat is $1\frac{1}{3}$ million dollars. The speed according to press reports is to be $\frac{20}{11}$kts. The reserve buoyancy of the American Holland boats has been gradually increased and the form of the superstructure is now ship-shaped in the bow.

The Holland type has been adopted also by the *Whitehead* firm in Fiume. The bow of the Whitehead boats is similar to that of an ordinary torpedo boat.

The Lake boats have likewise developed to larger size. The *Seal* carries torpedo-tubes in the superstructure.

In France a greater differentiation took place than in other navies. The two main types, the submarine and the submersible, co-existed and were developed simultaneously to greater sizes, but gradually approached each other. After the comparative trials in 1908 between submarines of the *Emeraude* class and submersibles of the *Pluviose* class it appears that the submarine was altogether abandoned. In five boats laid down last year the displacement is $\frac{830}{1070}$ts.

In Italy submersibles of the Laurenti type have been developed. They have the same principal features as the Laubeuf boats of which they may be considered a variety, but differ from them in some respects. The strength hull is not always circular, although in later boats this seems to be the case. Some have horizontal propellers for submerging. Some recent boats have three propellers for propulsion.

In Germany the Germania firm in Kiel constructs submersibles of the d'Equevilley-Germania type, likewise derived from the Laubeuf boat. The strength hull is cylindrical and is built up of several welded sections without frames. The sections are scarfed together, except one of the sections amidships which is connected to the others by bolted flanges so as to facilitate shipping and unshipping of the machinery. The ballast and fuel tanks are outside the strength hull amidships and at the ends. Only one internal tank, used for compensating for incidental variations in buoyancy, is fitted amidships. The boats dive almost on an even keel. The latest German boats are probably of about the same size as the English F-class.

II. A Discussion of the Principal Features of the Design of Submarine Boats.

SUBMARINES AND SUBMERSIBLES.

The "submersible" has already been defined as a submarine boat in which predominant importance is given to the requirements of service in the light condition, while the "submarine" is designed more particularly with regard to the submerged condition. Hence the ship-shaped form of the submersible and the spindle-shaped form of the submarine. The external ship-shaped form of the submersible is however attained without abandoning the advantage of the circular section which is maintained throughout an inner spindle-shaped "strength-hull", because it is the form best adapted to resist the pressures of the water. Between the inner and the outer shell are water-ballast tanks and oil tanks, whence the strength hull may be of small diameter well suited to resist great pressures without going to excessive scantlings. The outer hull, not being exposed to great pressures, may be lightly built and will yet in some measure protect the inner hull against damage by collision. At the same time the ballast and oil tanks may, with a relatively small addition in hull weight, be made very large, whence a great reserve buoyancy and great radius of action can be secured. In a submarine the tanks are chiefly inside the strength hull and cannot, therefore, be very large without unduly increasing the diameter of the hull and hence its tendency to collapse.

Speaking broadly, the submersible has better seagoing qualities and a higher speed on the surface than the submarine, but the form is not so favorable for driving under water. Most early boats were submarines. It was natural that inventors, especially those not acquainted with the requirements of naval service, should direct their efforts especially to navigation under water and that they should underestimate the importance of qualities required for work on the surface. At present the general trend of the development is towards the submersible type. Of recent years, therefore, the submarine, where it is still retained, has approached more and more to the submersible by an enlargement of the superstructure, which at the same time has been given a more ship-shaped form. In English submarines side structures have been added. The reserve buoyancy in the early submarines was only about 5 per cent. of the light displacement, but has been gradually increased to about 18 or 20 per cent. In submersibles, on the other hand, the reserve buoyancy has been reduced from about 72 per cent. in the *Narval* to about 35 per cent. or less in recent boats.

The submersible has a rather high centre of gravity and in submerged condition a low metacentre (centre of buoyancy), and hence small stiffness on account of the high position of the ballast tanks, while in the surface condition the stiffness is in some cases excessively great owing to the large area of the water-line. The submarine has a lower centre of gravity and, due to the low lying water tanks, it has a high metacentre in the submerged condition and small or moderate stiffness on the surface. The Laurenti type, where the ballast tanks are partly below the strength hull partly above or very high, are intermediate between the Germania and the Holland type in this respect.

In order to obtain sufficient stability in the submerged condition submersibles must generally carry a considerable amount of keel-ballast. This of course is a drawback, but also most submarines carry some ballast. Part of the ballast is generally detachable, often referred to as a "safety keel", to be let go in case of emergency. In passing from the light to the submerged condition and *vice versa* a point will exist where the stability is a minimum, being reduced by the presence of free water in the tanks. The designer must, therefore, carefully determine the conditions of stability in all intermediate positions in order to satisfy himself that a proper metacentric height is always maintained. If the stability vanishes at any point the boat may heel over to a considerable angle before equilibrium is restored or may even capsize.

STRENGTH OF HULL.

The hull of a submerged vessel is exposed to an external water pressure which is directly proportional to the depth of immersion. Already at a depth of 200 ft. the pressure is about 100 lbs. per sq. in., and since the depth of water in the ocean is generally more than 10,000 ft., boats cannot be constructed to withstand the pressures at all depths which they may encounter. It is therefore necessary to assign a limit to the pressure head which a boat is required to resist. Generally boats will have no reason to go deeper than required to clear the bottom of vessels on the surface, that is to a depth of about 75 ft., but accidentally they may descend involuntarily to greater depth. Usually the head to which submarine boats are tested is about 150 ft., although in some navies it is as much as 200 ft. A certain margin of safety is of course applied in the construction, but if the boat goes much beyond its test depth it is liable to collapse.

In most boats the strength hull is of circular section as stated above. The Whitehead boats and other boats of the Holland type have internal frames. As seen from the midship section of the Danish boat *Havmanden*, the Whitehead boats in some cases have oval sections

even amidships, because this form is convenient for boats designed for operating in shallow water. Some boats, such as those of the Germania type, have no frames. Other boats such as those of the Laurenti type appear to use the framework between the inner and outer hull as a means of stiffening the strength hull.

STEERING AND NAVIGATION.

Steering in a horizontal direction takes place as in ordinary vessels, but steering in the vertical plane has caused many difficulties to early inventors. As late as 1901 a German authority, Professor Busley, deprecated the value of submarine boats on that ground.* Mr. Holland introduced diving and emerging by inclining the boat at considerable angles, while most other inventors preferred to keep the boat as nearly as possible on an even keel and to effect great changes in depth by pumping water in or out of the boat, by means of horizontal propellers, or by so-called "hydroplanes". The last method is that which at present is mostly used in submersibles. Hydroplanes are similar to rudders—sometimes fitted amidships abreast of the centre of gravity of the boat, sometimes placed forward and turned the same way as the aft rudders. In all cases the object is to obtain an upwards or downwards force driving the boat laterally up or down. This method is generally considered safer than the "porpoising" used in the Holland boats. Once the desired depth is attained it is preserved by using the horizontal rudder in the same way as when steering a course on the surface, but with this difference, that even small deviations from the given course line (depth) are not here permissible. For guidance in steering a depth gauge and a clinometer are used. Steering in the vertical plane requires considerable skill and experience.

In order to navigate, the submarine boat must be provided with a reliable compass and, even when submerged, a view of the horizon must be obtainable at any time. An ordinary magnetic compass is not quite reliable even when placed in a conning-tower of bronze, but recently the advent of the gyroscopic compass has provided a means of accurately determining the direction. The faculty of vision when the boat is submerged, as it must be when making an attack, constitutes one of the most important and difficult problems connected with submarine boats. The water is practically opaque and it was therefore necessary in early boats, when going under water, to emerge from time to time so as to obtain a view from the conning-tower, but evidently this mode of navigation was anything but safe, since the presence of the boat was thus revealed to the enemy. Already in the "eighties" and "nineties" optical

*Transactions of the Institution of Naval Architects, London, 1901, p. 188-189.

tubes were introduced of simple construction, invented by Marié Davy in 1854 and gradually perfected. In its simplest form the optical tube had a mirror at each end inclined at 45° to the axis. The tube, being fitted watertight in the top of the boat, projected a foot or two above water when the boat was immersed to a certain depth and thus a view of a part of the horizon might be obtained, but the angle of vision was only one or two degrees, and the image was very imperfect. The mirrors were replaced by prisms, lenses were introduced and during the "nineties" several improvements were made, but not till about ten years ago was any serious progress made. Then in a few years the optical tube, or the "periscope" as it is now usually called, was developed to a high degree of perfection, enabling the submarine boat to perform attacks without showing anything but the top of the periscope occasionally above water, at the same time obtaining a perfect view of the enemy. The periscope was the last link in the chain of inventions which were needed to give to the submarine boat positive military value. The improvements in the periscope comprise a larger field of vision spanning an arc of more than 50°, as large as or greater than that of the human eye, convenience of observation, and the addition of means for measuring distances and indicating directions. The magnification of the object is only about 1.5, which is found to give to the observer the same impression as when using the naked eye. By using the utmost refinements of optical art and science a perfect image of unsurpassed clearness and distinction is obtained. Mechanical power is used for handling the tube, enabling it to be pushed up and down readily and quickly and to be turned round its axis. The length of modern tubes is up to 25 ft. with a diameter of about 6 in. The head of the tube projects from 15 to 22 ft. above the superstructure. Difficulties still exist due to the vibration of the boat and due to spray on the front glass, but they are of secondary importance. Instruments have been constructed by which an all-round view of the horizon can be obtained without turning the tube, but have not proved quite satisfactory.

VARIATIONS IN BUOYANCY.

In order to go from the light to the submerged condition and *vice versa* it is necessary to admit or to discharge water. Main tanks of great capacity must therefore be found provided with large sea-valves and powerful pumps. Means are provided also by which the water may be forced out of the tanks by admitting compressed air. Ordinarily the air is not admitted till the boat is on the surface, where only low pressure air is required, but a sufficient store of highly compressed air is carried by means of which the tanks can be emptied very quickly

in case of emergency, even when the boat is at a great depth. The time occupied in passing from the surface to the submerged condition should be not more than about from 4 to 5 minutes. This, of course, is a point of great military importance. Since the main tanks are always filled completely when it is desired to dive, it is necessary to fit one or more auxiliary or regulating tanks of moderate capacity to allow for variations in the specific gravity of the water and for changes in the weight of the boat due to consumption of provision, stores, etc. The consumption of fuel-oil is roughly compensated for by admitting water to the bottom of the oil tanks, which are thus always kept completely filled. The buoyancy of the boat in the submerged condition is so adjusted that a small "reserve buoyancy" remains, leaving always a tendency to rise to the surface. This tendency is overcome dynamically when the boat is in motion either by hydroplanes or by giving the boat a slight downward inclination by the head.

Small tanks, one at each end of the boat, permit an accurate adjustment of the trim (the longitudinal balance). Special tanks are fitted for compensating for such losses in weight as when a torpedo is fired and another is inserted in the tube. In some boats a so-called "floating tank" is fitted, connected with a continuously acting pump which is worked in conjunction with the horizontal rudders; this tank serves to compensate automatically for incidental variations in buoyancy occurring after the boat has got under way, notably those due to changes in the specific gravity of the water. A considerable amount of buoyancy can be obtained almost instantaneously in case of emergency by the release of the safety-keels referred to above.

The superstructure which is above water in the light condition is self-bailing. In some boats it is entirely and permanently open, serving only to provide a raised platform, but in most boats it is a watertight structure provided with large and numerous valves that can be readily closed when the boat is in light condition whereupon the superstructure will add to the reserve buoyancy and the stability.

VENTILATION AND HABITABILITY.

Space is always restricted in a submarine boat. When going on the surface the motor gives off much heat and requires a great amount of air for its combustion. It is unavoidable that some of the products of combustion, carbon monoxide and carbonic oxide, leak out from the engine. Also the men consume oxygen and produce carbonic oxide, and when charging the batteries free hydrogen is liable to be liberated, forming with the air in the boat an explosive mixture. Where the fuel is gasoline or other very volatile oil, it will evaporate at a low tempera-

ture and is liable to leak out into the boat; it is poisonous and is capable of forming an explosive mixture with the air. Hence it is necessary to provide very vigorous ventilation when going on the surface. In the submerged condition the problem would appear to be even more difficult. The available air gradually becomes vitiated, but it is found that the crew can live for several hours without any sort of air renewal or means of purification. This is due to the constant leakage which takes place from the compressed air system, a leakage which can never be entirely prevented. If desired, the carbonic acid, which gradually accumulates due to exhalation, may be removed by chemical means, or the foul air may be pumped out. Fresh air can be supplied from the compressed air reservoirs. There is, however, rarely occasion for resorting to such means. A greater difficulty is the escape of gasoline and poisonous fumes from the motor as well as from the battery. There is no convenient test for carbon monoxide suitable for use in submarine boats, whence it has been necessary to use white mice for indicating the presence of this poisonous gas to the effects of which these little animals are very sensitive. White mice breathe much more vigorously than human beings and will absorb carbon monoxide about twenty times as rapidly as man. Hence, long before man feels any discomfort, the mice will show symptoms of distress. When this occurs, and especially when the mice become asphyxiated it is time to ascend to the surface and to renew the air in the boat.

With proper precautions the crew may remain in the boat with all hatches closed for 12 hours or more, which is generally all that is required, since the boat can go to the surface as soon as darkness sets in.

Life on board a submarine boat is, however, very fatiguing and for this reason the time in which a boat can stay away from its base is very limited. The crew has to be changed at frequent intervals or it must be given time to recuperate, a fact which in many cases may limit the practical endurance of the submarine boat more than the supply of fuel. As matters stand now it may be said that the crew of a submarine boat ought to be relieved after two or three weeks' service.

PROPULSIVE MACHINERY.

For propulsion on the surface the gasoline motor was the first really successful engine. It was light, occupied small space as compared with the steam machinery and the combustion of fuel-oil was not more than about one-half pound per H.P. hour as against at least 1½ lb. per H.P. hour for steam machinery with oil-fed boilers. For small boats, of a displacement of from 100 to 300 ts. where weight and space were very restricted, the gasoline engine offered the best solution, but the

dangers by this volatile oil soon made it necessary to introduce heavy-oil motors, although they were in several respects inferior to the gasoline motors. While the latter are easy to start, special means are required for starting the former, and the consumption of fuel in heavy-oil motors, as for instance of the Koerting type, was about twice as great as in the gasoline motors. The last step in the development was the introduction of the Diesel engine, which although rather heavy and likewise burning heavy oil, has a consumption of fuel somewhat less than that of the gasoline engine. The nominal radius of action of recent boats of the largest size, driven by Diesel motors, is given as from 3000 to 5000 miles. The speed on the surface has attained 16 kts. in several boats and the designed speed in some boats now under construction is 18 or 20 kts.

The Diesel engine is the motor which to-day finds most favour in submarine boats, but with the increasing size of boats and the claims to higher speed it becomes increasingly difficult to produce motors of sufficient power. Units of from 800 to 1200 H.P. are under construction and there are usually two and in some boats three propellers. Many difficulties are met with and failures have occurred, whence steam power has been preferred in some boats as for instance in the French submersibles *Gustave Zédé* and *Nereide* of 1000 ts. displacement, which are to make 20 kts. Steam machinery has the advantages of reliability and durability, but it occupies much space and the problem of getting rid of the heat is difficult to solve. The radius of action obtainable with steam power on a given weight of fuel is much smaller than with Diesel motors.

The weight of Diesel engines as fitted in submarine boats is about 65 lbs. per H.P. as compared with about 50 lbs. per H.P. for gasoline engines and from 50 to 60 lbs. per H.P. for steam machinery inclusive of propellers and shafts.

For under-water propulsion electric power derived from a storage battery of lead accumulators still offers the best solution. Since the first appearance of these cells they have been improved upon in many technical details, and are now reliable and durable. They will stand complete charging and discharging more than 400 times, and under ordinary peace service conditions if carefully handled they may be expected to last about 5 or 6 years. The weight per H.P.-hour including outfit is by discharge in 3½ hours about 80 lbs., practically the same as in early accumulators. Lead cells permit great variations in power and are at their best at low rates of discharge, a most valuable quality for submerged work. They can be stowed low in the boat and add thus considerably to the stability. They occupy about 0.4 cb. ft.

per H.P.-hour, *i.e.*, less than any other source of energy at present available for this purpose.

Attempts have been made to introduce accumulators of different type but so far without success. The Edison alcalic iron-nickel cells are about 10 per cent. lighter, but occupy at least 25 per cent. more space; they cannot be so rapidly discharged as the lead accumulators. They cost more than three times as much, but are more durable. It appears that recently improvements have been made and better results are claimed by the makers. Practical service tests are required to determine the relative merits of these cells.

The total energy accumulated by storage batteries is necessarily small and rarely allows more than a speed of about 10 kts. for 3 or 4 hours. Recently boats have been designed for 11 or 12 kts. The radius of action at maximum speed of large boats is about 30 or 40 miles, at reduced speed about 100 miles.

The excessive weight of the plant for underwater propulsion is the more unfortunate, since the weight available for propulsion is already very small as compared with that in ordinary torpedo-boats. The reason for this is that the hull weight is extremely great, occupying about 20 per cent. more of the total displacement than in an ordinary torpedo-boat. Only about 30 per cent. of the displacement of a submarine boat can be devoted to machinery and fuel as against about 50 per cent. in a torpedo-boat. Moreover the plant for underwater propulsion comes as an extra addition. It is evident, therefore, that submarine boats can never compete with torpedo-boats as to speed and radius of action.

Great efforts are being made to devise a type of machinery that can be used both on the surface and submerged and especially one by which the propulsion under water does not entail any extra weight, but no satisfactory solution has yet been obtained. Any process based on combustion involves the storage of atmospheric air or oxygen, but a storage of these gases in sufficient quantities for underwater propulsion requires excessive weight and space. The discharge of the products of combustion is liable to reveal the presence of the boat.

M. d'Equevilley has proposed a solution which is being tried in the French submersible *Charles Brun* and probably also in a German boat.* He uses an ordinary boiler with oil fuel and a steam engine on the surface, but when the boat dives under water the exhaust steam is led to a concentrated lye of sodic hydrate (NaHO) which absorbs the steam under strong evolution of heat and thus serves as fuel in a secondary "soda boiler". This process goes on till the lye is saturated. When

* Jahrbuch der Schiffbautechnischen Gesellschaft, 1913, pp. 131-138.

the boat comes to the surface and steam is available from the primary boiler, the soda lye may again be concentrated by evaporation of the water which it has absorbed, and the boat is ready for another submerged run. This plan offers the advantages that there is no change of motor, the same engine being used under water as on the surface, and there are no products of combustion. The machinery can be forced without difficulty and relatively high power attained both in light and submerged condition. No electric motor is needed. On the other hand, the system requires the addition of special soda-boilers and a hot water reservoir; the plant occupies so much space that the available weight cannot be fully utilised; the centre of gravity of the machinery is high and requires extra ballast to be carried; the radius of action on the surface is necessarily smaller than with an explosion motor; there is likely to be a strong corrosion due to the soda, and isolation for heat will probably cause difficulties. The soda-boiler plant appears, however, more promising than other power plants so far proposed for this purpose.

ARMAMENT.

The principal armament of submarine boats is the Whitehead torpedo. English boats of the F-class are said to carry six 21 in. tubes and French boats of the latest type eight tubes. Recently large submarine boats have been equipped with an armament of light guns in disappearing mountings. Later English boats carry two 3-in. guns so mounted that they can be used against air-craft as well as against other vessels. When not in use, the guns and mounts are housed in the superstructure.

Attempts have been made to design mine-laying submarine boats, a problem which is evidently of considerable interest. As far as known, Russia is the only power that prior to the war had built a boat for this purpose, viz., the *Krab*, designed for dropping mines when in surface condition. A boat so designed that mines could be dropped when in the submerged condition would be of greater value, but there are technical difficulties in releasing mines under water, in compensating for their weight and in determining their exact location.

SIGNALLING.

The faculty of communicating with other vessels whether on the surface or submerged is one of great military importance for the submarine boat. For service on the surface wireless telegraphy has been successfully used for several years, but for submerged service it is only quite recently that means of signalling has been devised which seem to

promise good results. It was at first, when the submarine bell was invented, attempted to use it for signalling, but it was found that it was not well suited for sending messages by the Morse system. No practicable solution was discovered till an Austro-Hungarian physicist, Mr. H. C. Berger, showed the way by his experiments undertaken in the Danube at Budapest on the transmission of longitudinal vibrations through water. A wire of 2 in. in diameter was set into vibrations by the friction of a hand-driven silk-wheel moistened with alcohol whereby a clear and sustained note was produced, capable of being sent in dots and dashes of the Morse code. The wire was fastened to a plate in contact with the water, and was anchored at the other end to some fixture, but the tension of the wire was immaterial. The identical apparatus used by Berger was fitted in one of the United States submarine boats in 1911 and readable signals were transmitted over a range of two miles. Still better results were obtained with steel ribbons and power-driven exciters, by means of which distinct signals were transmitted over a distance of 10 miles. Recently electrically-worked oscillators, invented by Professor R. A. Fessenden, have been used instead of the wire ribbons and have given very promising results. This mode of signalling is sometimes referred to as the "submarine wireless system", but it must be distinctly understood that the transmission through the water takes place entirely by sound waves emanating from a diaphragm plate which may be part of the ship's side. The receiver is a similar plate in another ship similarly connected. This appliance is now being developed by the Submarine Signalling Company of Boston and, apparently, with considerable success.

SAFETY, SALVAGE, AND TRANSPORTATION.

As a consequence of the numerous and serious accidents which have befallen submarine boats of recent years, much has been done to increase the safety of this craft. The hull is subdivided more minutely than formerly by bulkheads of sufficient strength to withstand the maximum water pressure. A buoy provided with telephone connection is fitted in the superstructure and can be sent to the surface in case of emergency, enabling communication to be established with the outside world. In some boats the men are provided with diving suits and helmets, enabling them to escape or to remain for a longer time in the boat when it is flooded. Great precautions are taken to prevent the fumes from the storage battery from entering the working rooms of the boat. The battery is in many boats placed in an entirely separate, airtight, well ventilated compartment. Vessels of special type, "salvage docks", are built for the purpose of raising the boats when they have sunk to

the bottom in damaged condition. Shackles are fitted on the top of the boats for this purpose

Special vessels are constructed also for the transportation of submarine boats.

SIZE.

From the moment that submarine boats were taken into practical service, claims to increased seagoing capability, speed, radius of action, and better living conditions on board were advanced by the naval officers. These claims could be best met by an increase in size and we can understand, therefore, that size has steadily increased ever since the beginning of the century. Boats were then less than 100 ts. fully submerged and are now being built of about 1200 ts. displacement. The reason why the displacement has not increased much faster is chiefly the difficulty of providing motors for propulsion of sufficient power. By an increase in size, moreover, the boats become more difficult to handle under water, especially where the depth is small, but probably this difficulty would be of secondary importance for ocean-going boats, should such boats become a reality. The high cost of large boats will put an early limit to their number, the price per ton being almost three times as high as for battleships.

MILITARY VALUE.

The great military value of submarine boats has been demonstrated in the present war. At the present stage of development submarine boats afford not only the best means of defence of our own harbors and coasts, but may be used also for offensive purposes in the open sea and on the coasts of an enemy up to a distance of some five hundred miles from their base. The large boats of about 1200 ts. displacement now under construction probably have a still greater radius of action.

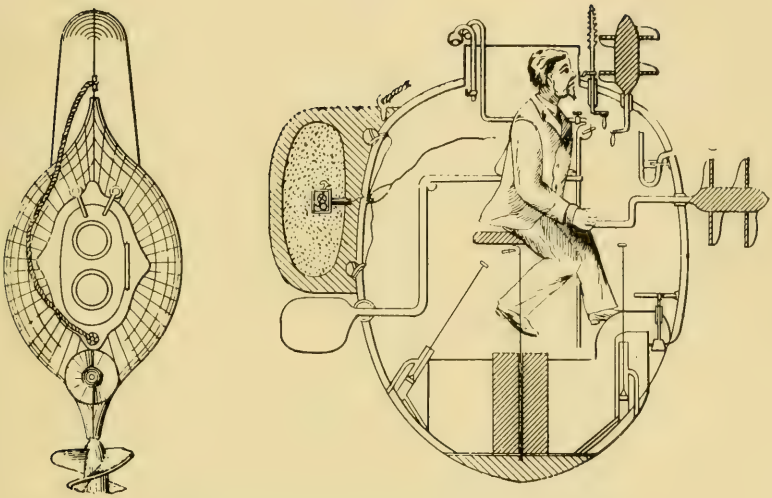
A peculiarity of the submarine boat is its faculty to carry out an attack with relatively small risk once it has gotten into position, in which respect it differs radically from the ordinary torpedo boat which must always be prepared for great and almost unavoidable sacrifices in order to carry out a successful attack. The greatest difficulty with a submarine boat is to bring it into position for attack.

The future development of the submarine boat is likely to be steady but slow. In the meantime it is probable that also the means of attack and defence possessed by the battleships against submarine attack will progress. Evidently, the first point for the battleship is to detect the submarine boat. Once detected before it has reached within striking range the submarine boat can generally be avoided,

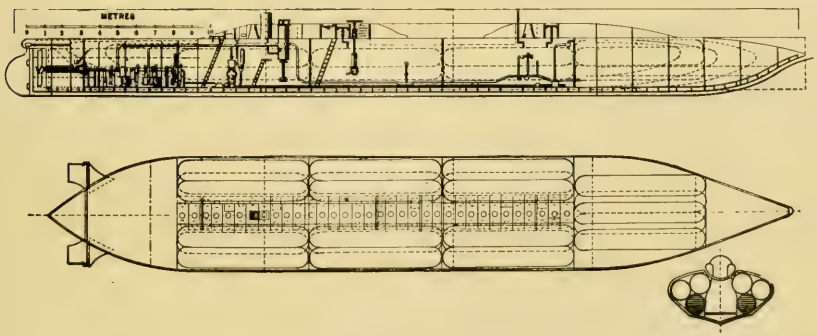
because its speed under water is so slow relative to that of the battleship. The detection of a submerged boat is, however, a difficult matter, the only visible point being the head of the periscope, which needs to be shown above the surface only from time to time. In still water the periscope is fairly visible by the wake which it makes on the surface when emerging, but in rough and misty weather it is extremely difficult to detect. Detection from air-craft is under certain circumstances fairly easy and this mode seems to promise a great deal. When the periscope is discovered, it will be at once subject to a hail of projectiles from light guns, and if it is hit the boat will be blind and helpless. If, after that, the boat shows its conning tower above the surface, it will generally be exposed to destruction by artillery fire.

Seaplanes or other types of air-craft may possibly become a dangerous enemy of the submarine boat not only in helping to detect it but also by direct attack with bombs. When the boat is submerged it is quite helpless against bomb dropping. Even very light bombs are likely to prove destructive, and since the air-craft is in no danger of counter-attack from the submarine boat, it can go very low and hitting should not be a difficult matter. The submarine boat cannot even observe a seaplane when immediately over it. A further development of the seaplane is, therefore, likely to prove extremely dangerous to the submarine boat. Numerous small patrol-boats properly equipped for attacking the submarines with gun, ram and other weapons are likely to prove effective in the vicinity of the coasts.

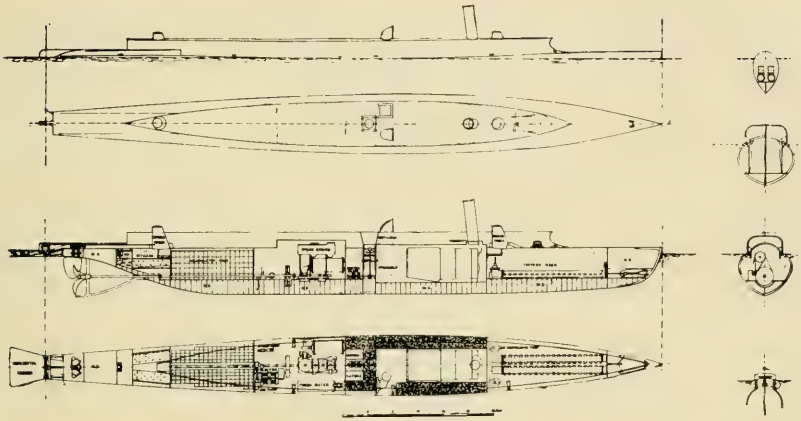
While the active or offensive means of defence are in this case as elsewhere the most effective, the battleship possesses means of defence of a passive nature such as watertight subdivision, elastic bulkheads and underwater armour, which may be still further developed, but experiments and war experience are required to throw light on the problems involved. The superior speed of battleships is of course in itself a means of protection. On account of the present limited range of submarine boats and perhaps especially on account of the limit to the endurance of the personnel, they do not render the powerfully armed and well protected artillery ships superfluous. Large seagoing battleships and battle cruisers are yet required in order to control the ocean, but as matters stand now, the smaller enclosed seas such as the Baltic, the North Sea, the Mediterranean, the Yellow Sea and other similar waters may be practically controlled by submarines and by light, fast vessels. In the presence of an active enemy well provided with submarine boats large vessels cannot operate in such seas except under the greatest precautions, going at high speed and using all possible means of defence.



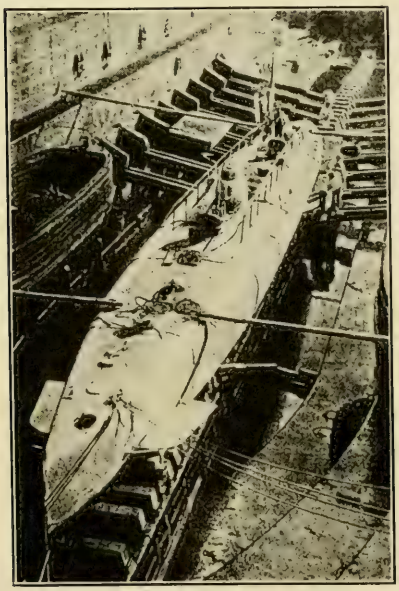
BUSHNELL'S BOAT: *THE AMERICAN TURTLE.*



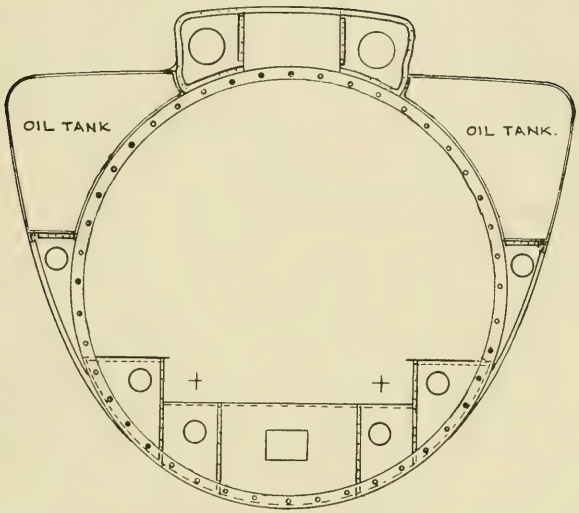
LE PLONGEUR.



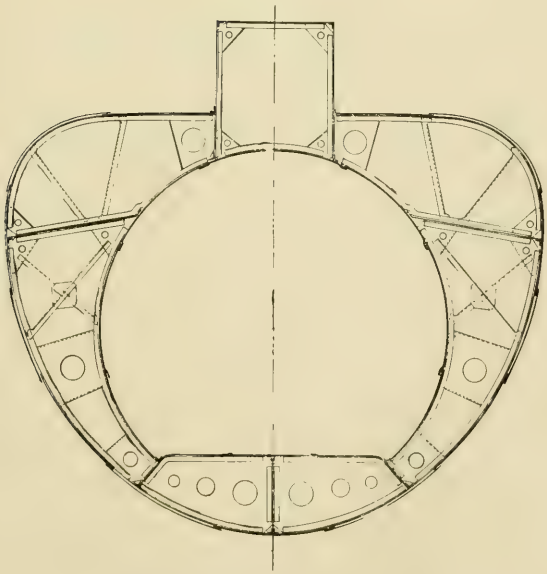
DIVING BOAT PROPOSED BY THE AUTHOR IN 1888.



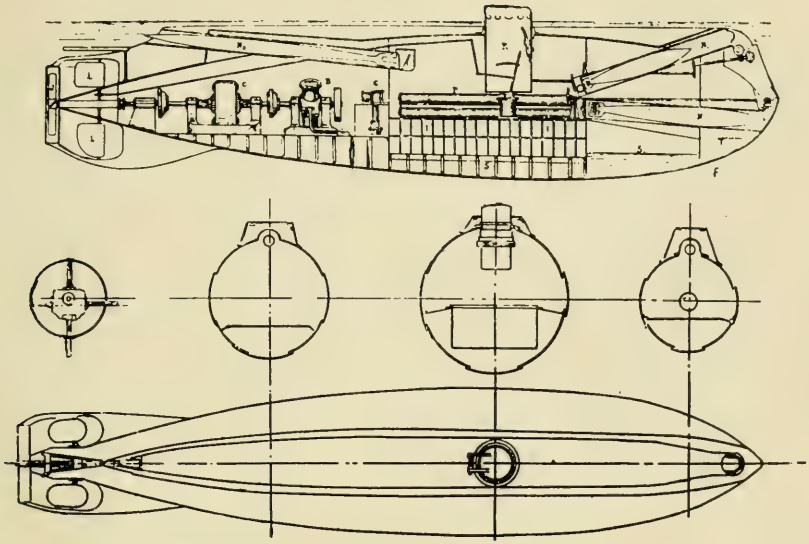
THE NARVAL: THE FIRST LAUBEUF BOAT



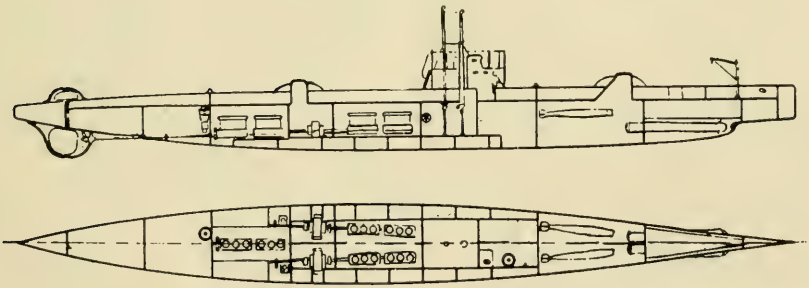
SUBMERSIBLE OF GERMANIA TYPE.



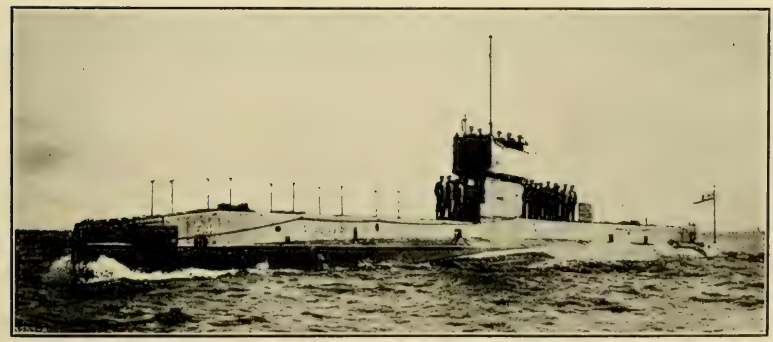
SUBMERSIBLE OF LAURENTI TYPE.



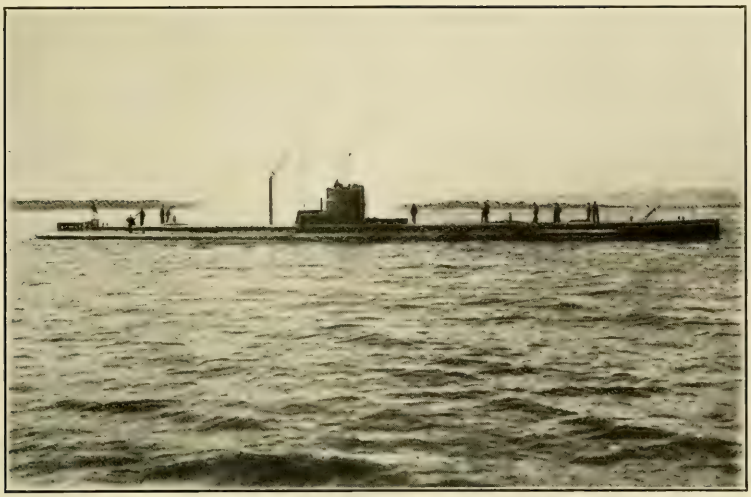
THE HOLLAND.



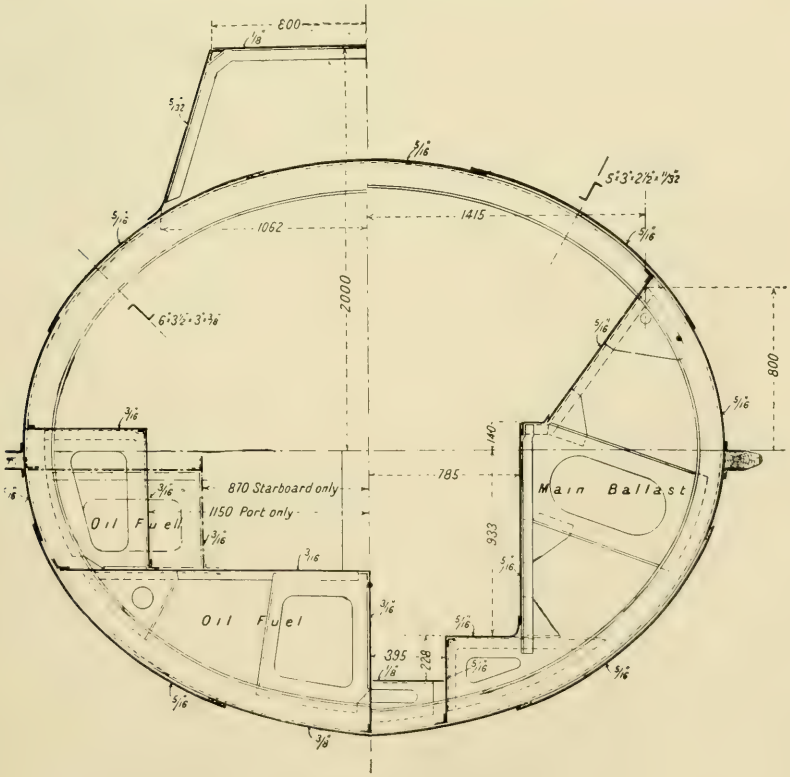
THE FOCA: ITALIAN SUBMARINE.



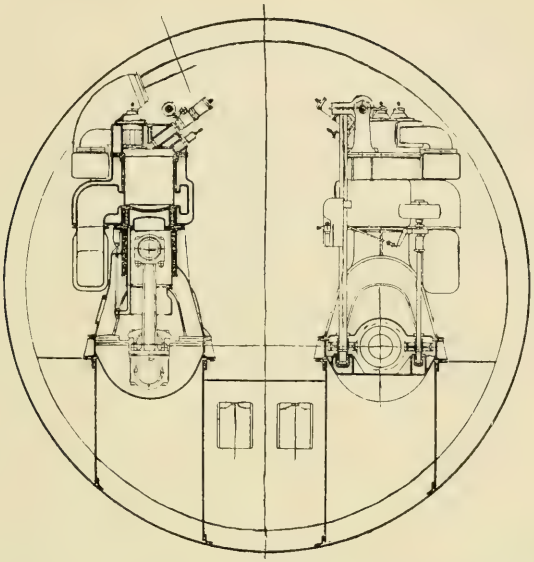
H.M. SUBMARINE-BOAT E 4.



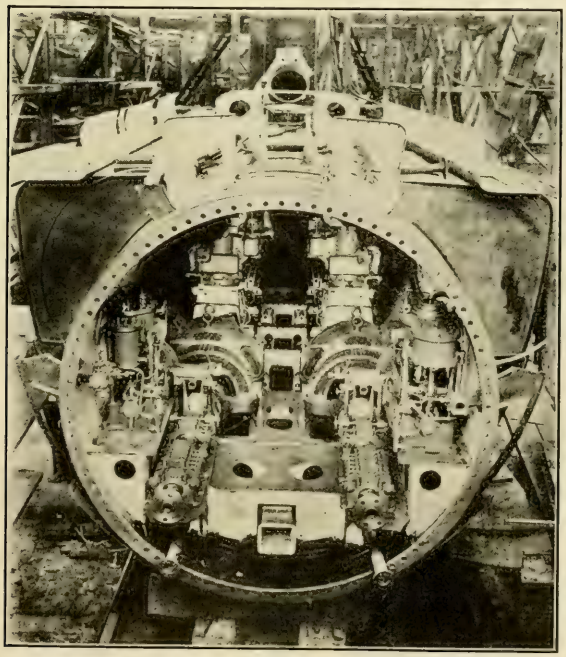
GERMAN BOAT U 15. DESTROYED IN THE NORTH SEA BY BRITISH WARSHIPS.



SUBMARINE *HAVMANDEN*—MIDSHIP SECTION.



REVERSIBLE SIX-CYLINDER DIESEL MOTOR FOR SUBMARINES, GERMANIA TYPE. 900 H.P. 450 REVOLUTIONS PER MINUTE.



FROM KRUPPS' GERMANIA WORKS IN KIEL.
NORWEGIAN SUBMARINE *KOBBEN*.

SIR SANDFORD FLEMING, K.C.M.G., LL.D., M.INST., C.E., LOND., ETC., ETC.

BY the death at Halifax on July 22 last of Sir Sandford Fleming, The Royal Canadian Institute has lost its most distinguished member, the last of the small company of men who away back in 1849 formed themselves into a Society for the promotion of Science in Canada. He was the moving spirit of the time; to his energy and unwearying perseverance was due the fact that the flickering flame then kindled was not allowed to be extinguished. He has himself related how, when all interest in the Institute seemed to have died out and the attendance at a regularly called meeting had dwindled to two, those two (himself and another) unanimously passed a resolution that the Institute should from that date meet every Saturday evening. This bold action had the desired effect, and never since has there been any doubt as to the vitality of the Institute. He took a large part in framing the Constitution and By-laws of the infant Society, and when, after two years of struggle, so much progress had been made as to warrant an application for incorporation, by him the Charter was drafted under which it has reached its present high position.

Amid all the large and varied occupations of a more than usually busy life, his interest in the Institute has never flagged. A long series of contributions from his pen to the Publications of the Institute bears testimony to this fact, as well as to the wide range of his studies and attainments.

While still a young man with limited means he conceived the idea of establishing an Endowment Fund for the Institute, and, in order to attain his object, in 1852 he applied to the Canada Life Assurance Company for a policy of £1,000 which was issued in January 1853, the proceeds to be for the benefit of the Institute. The policy was fully paid up in 1899. In 1892 he deposited in the hands of the then President, Mr. Arthur Harvey, the sum of $1,000 to be expended in prizes for essays to be called for on "The Rectification of Parliament" on the basis of an elaborate paper by himself on "Electoral Representation", which was published as a Supplement to Volume IV of "The Transactions". Ten essays were sent in as a response to the call, but as none of them were deemed satisfactory as a solution to the problem proposed, no prizes were awarded. Sir Sandford, however, did not take back the money but in a letter to the President of December 12, 1899, he added it to the $4,000 of the insurance, saying: "These two sums together amounting to five thousand dollars I propose to place at the service of the Institute

for the purpose of forming the nucleus of an Endowment Fund in the hope that it will from time to time be augmented from other sources. My wish is that this sum of $5,000 shall be held as a Trust Fund to be invested and the interest derivable therefrom to be alone used for special and desirable objects. I leave to the Council of the Institute full power and authority to direct the special objects to which the derivable income may be applied."

It will be unnecessary here to make more than a passing reference to his great services as an engineer to Canada and the Empire in connection with the Northern Railway, now a part of the Grand Trunk System, the Intercolonial Railway, the Newfoundland Railway, the Canadian Pacific Railway, and the Grand Trunk Pacific Railway (for it was he that suggested the adoption of the Yellowhead Pass through which the last named road traverses the Rocky Mountains).

Suffice it to say that his name and fame are indissolubly connected with them all. It is with his work as a Scientist and a Publicist that the Institute is more intimately concerned, inasmuch as its Publications show his researches in geology which enabled him to discuss the formation of Toronto Harbour, the Davenport Gravel Drift, the Valley of the Nottawasaga, and the Oil Wells of Enniskillen; in astronomy and geography by his exhaustive articles on universal or cosmic time, the reformation of the time system of the world, and the establishment of a prime meridian as a zero common to all nations; History he illustrated by valuable articles on ocean steam navigation, on early steamboats, and the story of the steamship; Economics craved his attention in his suggestions for the improvement of postage stamps. His work as a Publicist has already been alluded to in connection with electoral representation and parliamentary reform, but perhaps more important than all else were his statesmanlike labours for a world-encircling telegraph cable connection between Great Britain and the Dominions beyond the seas. The consolidation of the Empire and Imperial unity were among his most cherished dreams, long before the present gigantic struggle in Europe awoke Britons everywhere to the conception of the Empire as one and indivisible. For this he wrought indefatigably by speech and pen, attending conferences and councils and congresses, travelling into all the quarters of the globe and emphasising his views wherever and whenever he had the opportunity.

A life such as this could not fail to bring to him honours and rewards. Four universities conferred on him honorary degrees; innumerable learned and scientific societies were proud to enrol his name on their list of members, and Royalty made him a Knight Commander of the most distinguished Order of St. Michael and St. George. He attended the Conversazione held in commemoration of the Jubilee of the Institute

SIR SANDFORD FLEMING, K.C.M.G., LL.D.

in 1899, not simply as a member, but as Chancellor of Queen's University, Kingston, which high office he held uninterruptedly from 1880 till his death.

It was hoped that he would be present on the occasion of the meeting at which the signal honour was bestowed by His Majesty the King on the Institute in permitting the prefixing of the word "Royal" to its title, but unhappily the infirmity of old age prevented, and instead he wrote a touching letter to the President, the reading of which was listened to with great interest, after which he was unanimously elected Honorary President and his two sons were declared members.

One of the last evidences of his devotion to the Institute was the placing of a marble tablet on the wall of the Memorial Tower at Halifax erected at his instance commemorating the centenary of the establishment of Parliamentary Government in Nova Scotia, being an enlargement of the crest of the Institute, which by the way was designed by him sixty-five years ago. The last years of his life were spent at his family seat, "Winterholme", Ottawa. Born at Kirkcaldy, "the lang toon o' Fife", Scotland, on January 7, 1827, he died at Halifax, N.S., on July 22 of this year, having thus completed eighty-eight years and six months. His funeral at Ottawa was one of the most representative ever seen in the capital, all classes, including many from outside the city, thus manifesting the profound respect in which he was held. The Institute was represented by the President, Frank Arnoldi, K.C.

His portrait in oils, painted by Mr. J. W. L. Forster, adorns the wall of the Institute building. In presenting it on November 5, 1892, Mr. Forster said, "There are not many ways in which I can directly advance the Scientific Departments of the Institute, but this task was undertaken with the hope that in some way it would serve to encourage and deepen the interest in the work you are doing. I was moved to the act also because in my humble opinion no one better deserves this recognition at your hands than the subject of the picture in view of his services in the past and present relationship to the Institute, and I was prompted to this by the knowledge that what is mortal of men will vanish from our sight, and there are men whose memory is worthy of being cherished. The hope is indulged in that this portrait will by this service be prized for generations to come." In return for this graceful action Mr. Forster was made a Life Member.

Tall and of commanding presence, Sir Sandford physically was emphatically a handsome man; intellectually, he was a giant; socially, he was a delightful companion; morally, he was without stain; religiously, he was a devout and reverent servant of the Most High.

Multis ille bonis flebilis occidit.

G. K.

INDUSTRIAL RESEARCH IN CANADA.

To the Members of the Royal Canadian Institute.

Ladies and Gentlemen:

Before proceeding with the subject which I have chosen for my inaugural address, namely, Industrial Research in Canada, I must first of all express to you my appreciation of the high honour you have conferred upon me in electing me to be your President for the coming year. Owing to limitations imposed upon my time I may not be able to preside at as many of your weekly meetings as a proper fulfilment of my duties demands, but if I fail in this regard, I know that my deficiencies will be met by the kind and generous co-operation of our Vice-Presidents, Mr. J. Murray Clark and Dr. A. C. McKay, Principal of the first Technical Institute of Canada, which has been inaugurated recently with such marked success, and which, with good warrant, is a source of great pride to us all. In the second place I wish to take this opportunity of expressing to our past President, Mr. Frank Arnoldi, K.C., our sincere appreciation of his services in emphasising the importance of the functions of the Royal Canadian Institute in our midst, in inaugurating a Bureau of Industrial Research in connection with our organisation, and in stimulating and promoting with zeal and patient determination the consideration of matters connected with the subject of Industrial Research.

I also wish on this occasion to give expression to the sense of loss we all feel in the death of Dr. George Kennedy, which took place in June last. For two years he was President of the Royal Canadian Institute, and for thirty years he was the editor of its Transactions. He attended the Saturday evening lectures perhaps more regularly than any other existing member of our organisation and he took an unfailing and helpful interest in everything which had to do with the welfare of the Society. He devoted all his hours of recreation to science and the works of philanthropy, and on passing away made provision for promoting both of these objects, the Institute itself being one of his beneficiaries. The memory of his presence with us is one that we shall always cherish, and the purity of his aims and the single mindedness with which he regulated the conduct of his life will long serve as a model for us all.

I. CONSERVATION OF RESOURCES AND DEVELOPMENT OF INDUSTRIES.

In dealing with the question of Industrial Research in the brief time at my disposal the key note of what I shall have to say will be "The Conservation of our Natural Resources, and the Scientific Development of our National Industries".

AGRICULTURE.

Three of our chief sources of wealth, I may point out, are our agricultural lands, our cheap electrical power, and our mineral deposits. Of these the agricultural industry is by far our greatest national asset. The importance of this industry was early perceived by our Governments and Legislatures, and due provision has been made already for its proper development. Through the agency of the Dominion Experimental Farms inaugurated by the late Dr. William Saunders and through the activities of the Ontario Agricultural College under the Presidential guidance of Dr. Mills, and Professor Creelman, as well as by the praiseworthy work of the late lamented Dr. C. C. James, great advances have been made in the selection of the most suitable seed grains, the best breeds of dairy cattle, horses and other farm animals, and vast improvements have been made in recent years in the preparation, storage and transportation of our dairy products. From what has been accomplished so far we may safely say that our agricultural industry is now on an eminently satisfactory basis, and that it is developing on sound lines. Much can still be done, however, to ameliorate the disabilities of farm life, by improving roads, by increasing facilities for education, by adding to the comfort of farm dwellings and the beauty of their surroundings, and by a more extensive use of electric power in farm operations. Speaking generally, too, I may be permitted to say that our agricultural lands are not as intensely fertilised as they should be, and production is not as much by half as it could easily be by proper treatment of the soil. And we have the remedy at hand if we would but use it. The vast deposits of calcium, potassium, and phosphate-bearing minerals in Canada require but to be worked to furnish us with unlimited supplies of mineral fertilising agents. Our electrical power, too, could furnish us with vast supplies of nitrates if we would but apply it. At Niagara Falls, Ontario, we have already in the American Cyanamide Works, an industry of some thirty-thousand horse-power capacity in which thousands of tons of fertilisers made by the extraction of nitrogen from the atmosphere are manufactured each year. But the whole of this output goes to the country to the south of us, and is used to increase the pro-

duction of the cotton fields of the Southern States. This great industry moreover, is owned and controlled by the interests which hold these cotton-bearing areas, and the output though manufactured by Canadian developed power is not available for the fertilisation of our own fields.

It is but one example of how a large percentage of the electrical power developed on the Canadian side of the Niagara River is sequestrated. Through lack of enterprise on our part and through concessions granted to foreign controlled organisations a large proportion of our electrical power is now diverted from Canada and is being used to develop the industries and increase the production and the wealth of our neighbours to the south of us. This is not as it should be. And I venture to suggest that if we would conserve one of the greatest sources of our national wealth, we should see to it at once that the exportation of electrical power is gradually diminished and that it ultimately ceases. This is the policy I may add that we have so successfully pursued in conserving our supplies of natural gas. We should seek to establish on our own side of the border all forms of industry in which electricity and its power capabilities can be used. Moreover in this electrical power we should never forget that we have at hand especially in what is known technically as the "off peak load" a supply of energy which might with proper development be used to replace in part at least the coal which we obtain at ever increasing cost from the United States. The time will come, yes, I believe it is near, when the export of hard coal from the United States to us will cease. We should be prepared for this eventuality and should systematically proceed to develop to the utmost limit the power capabilities of every fall of water throughout the whole length and breadth of Canada. Along that path lies national safety and national wealth and prosperity. With the example of the successful operation of the central heating plant of the University of Toronto before us we see what a simple engineering problem it is to heat a large group of widely scattered buildings. The whole of the city of Toronto could be readily and easily heated from a number of central heating stations just as it is now supplied with water and illuminating gas. I venture to suggest that steps should be taken immediately to develop this field. We could I believe to a considerable degree heat our towns and cities with the hydraulic power which at the present time we are either allowing to go to waste or which we are failing properly and efficiently to develop.

MINERALS AND METALS.

At the outbreak of the war it was found that the supply even within our Empire, of such metals as zinc, nickel, mercury, and the rarer metals,

tungsten, molybdenum, and platinum was largely under the control of alien enemies. Vast stocks of these metals had been accumulated in alien countries and the treatment of the ores of these metals had practically slipped into their hands from our own.

As an illustration of what I have referred to I may cite the case of tungsten. This metal as you may know is largely used for metallic filaments of electric lamps and for hardening steel-cutting tools. As an example of what was going on previous to the war, I may say that the whole of the output of Burma went to Germany, and the world was dependent on her for a great part of its supply of this metal as well as of the alloy ferro-tungsten. Moreover the monazite sands of Travancore were controlled by her and she also regulated the price and the output of this mineral and the production from it of thorium nitrate, thereby controlling also the gas mantle industry. In regard to tungsten, drastic and immediate action was necessary in order to meet our requirements in carrying on the war but for some extraordinary reason since 1914 there has been a steady drop in the production of tungsten from Burma. In January, 1915, the exports from that country were 232 tons, while in January, 1916, the output diminished to 217 tons. Even when the control was in our own hands the influence of the enemy was still felt. A number of coolies were sent to Tavoy to meet the requirements but still tungsten was not produced in anything like the quantities expected. The Government of Great Britain has now, however, sent mining engineers to supervise the production and no doubt the situation will be altered. I mention these things to show you into what a pitiable state we had fallen through our neglect of matters of vital importance in connection with the mineral industries of the Empire. Attention should be drawn here to one particular industry which has been developed in Canada through the prosecution of the war. For some years Professor T. L. Walker and others followed by Mr. G. C. Mackenzie and the Staff of the Mines Branch made a special study of the deposits of molybdenum ores in Canada and of the treatment of these ores, and as a result of this work the Mines Branch was enabled to point out to the metal industries of Great Britain that we had in our midst considerable deposits of molybdenum, and that this metal could be used largely in place of tungsten in the hardening of steels. But the information fell on deaf ears until the outbreak of hostilities when, with the supplies of tungsten largely diminished, a demand arose at once for the molybdenum. I am glad to tell you that the production of this metal has now become a very important and profitable industry in our country.

We have been taught the lesson and at a terrible cost that we must preserve our metals, first of all for our own use. We have vast resources

in minerals in Canada, but some of them will require special treatment. New processes will have to be devised for treating the ores. For example, I might cite the case of zinc and phosphorus. We have in Western Alberta and in British Columbia large deposits of zinc ores and of phosphate-bearing minerals. It is true, we do not know as yet how to treat them economically, but methods can and will be devised if we set our hearts on it. There is no reason why we should be dependent on other countries such as Germany for our supply of such vital commodities. Norway and Sweden have shown us what can be done by the application of electricity to the solution of such problems and with our extensive waterfalls we have at hand the means of producing electrical energy at the lowest possible cost. Efforts should be made to conserve it for our own use and research should be directed particularly to the development of its applications in the treatment of ores.

While dealing with the question of metals and minerals it might not be out of place to refer here to a movement which has been recently inaugurated by The Iron and Steel Institute, The Institute of Metals, The Institution of Mining Engineers, and The Institution of Mining and Metallurgy of Great Britain for the formation of a central Department of Mines and Metals in Great Britain to protect and advance the economic interests of British mining and metallurgical industries and to stimulate the development of the mineral resources of the Empire. As is well known there are well organised Departments of Mines in Canada and in some of the other Dominions but up to the present time there has been no Department of Mines in the centre of the Empire. In the plans which are being formulated it is proposed that the duties of the projected Department of Mines and Metals when established should include:

1. The making of arrangements for expediting the completion of mineral surveys of the United Kingdom and of the Crown Colonies and other British Possessions.

2. The systematic collection and co-ordination of information bearing on the occurrence, uses and economic value of minerals. Some of this information should be promptly and widely disseminated in summarised form to those interested in the industries, through the medium of the existing publications of the Institutions directly concerned.

3. The co-ordination and dissemination of information on mining laws, development of mineral areas, output, processes of extraction, plant, capital employed, markets, etc., etc.

4. The stocktaking in a general sense of the mineral resources of the Empire and the review from time to time of the position of each mineral or metal to ensure that the mineral wealth of the Empire is being developed and exploited with due regard to imperial interests.

5. Generally to advise the Imperial Government on all questions bearing on the mining and metallurgical industries. To perform this function efficiently it is essential that complete information should be available and also that the industries concerned should be consulted through their respective organisations.

The institutions to which I have referred have long felt the necessity for such a Department as that proposed but since the outbreak of war and the consequent revelation of the dangerous position into which these vital Imperial interests had been allowed to drift, the necessity has been demonstrated over and over again. It is not too much to assert that if a properly organised and efficiently conducted Department of Mines and Metals had been established in Great Britain much valuable time, many lives and vast sums of money would have been saved to the Empire in the course of the war.

DEPARTMENTAL CO-OPERATION.

It is a matter of common knowledge that in the activities of the permanent departments of the Governments of the different states constituting the British Empire there is not the active co-operation that should prevail if efficient progress is to be secured. Perhaps I may be permitted to cite an example or two of a defect of this kind which was recently brought to my attention. The Geological Survey of Great Britain as you all know, has a magnificent record to its credit. Its operations in the British Isles have been most complete and its reports are most voluminous and very exhaustive. It has happened, however, that after its reports have been presented to Parliament they have been carefully filed away and no special attempt has been made to bring their contents in a definite, particularised, and effectively useful manner before the industrial organisations of the country. When the War broke out it happened that one of the largest refining and reduction works in England found their supplies of a particular flux required by them in the treatment of their ores entirely cut off. The firm had been accustomed to import the flux from mines under the control of one of the Central Powers. A representative of the Institution of Mining and Metallurgy happening to call on this firm learned of their dilemma, and to the chagrin of its members pointed out that the Geological Reports mentioned above contained a detailed account of large deposits of this particular flux situated in England within 10 miles of their works. It is needless to tell you that in a very short time a light railway was constructed between the deposits and the works and the firm is now rejoiced to find that it can carry on its operations without let or hindrance and at a greatly reduced cost.

Again, before the war it was customary for the manufacturers of ordinary commercial glass articles to import from Belgium the sand used in their manufacture. The loss of this country to the enemy immediately cut off the supply. Search however was instituted, and it was soon found that sand equally suitable existed in large quantities in the British Isles. We have heard of the folly of carrying coals to Newcastle, but it will be difficult to find examples of economic folly more prodigious than the two which I have cited.

I might also cite an example of the lack of departmental co-operation in our own country. A few years ago it became a matter of considerable interest to ascertain if radium-bearing minerals existed in deposits of any extent in one of the Provinces of Canada. The action which was taken in the matter—and I have no doubt that such action was taken in good faith and intended for the best—was to offer a reward of some $25,000 for the discovery of such minerals in paying quantities. Up to the present, I believe, no part of the reward has been paid. Now in the procedure followed in this case, the Department referred to was quite unaware of the existence of a staff of trained scientists in another Department of the same Government which had gained world wide recognition for its researches on the properties of radium-bearing soils and minerals and which, if asked to do so, could have indicated a very simple way of making a complete survey of the Province, which would give such information as would enable one to say whether radium-bearing minerals existed in any considerable quantity or not. Moreover, the methods which would be applied in this survey are of such a sensitive nature that if deposits of the minerals sought for did exist it would be possible to locate them with ease and considerable precision.

These are but two or three illustrations of our lack of co-ordination in effort, but they serve to show what could be done if proper machinery were devised to co-ordinate our activities and to work out in detail a broad scheme of scientific co-operation.

II. NATIONAL ORGANISATION FOR INDUSTRIAL RESEARCH.

Coming now more particularly to the subject of my address, namely, the establishment of an organisation for stimulating and fostering research as a basis for our manufactures and industries, we are faced with the problem of how to bring such a project into operation with the greatest efficiency and the least possible friction.

UNIVERSITIES AND INDUSTRIAL RESEARCH.

The view is held in some quarters in Canada that the direction of research work, both industrial and purely scientific, should be placed

under the control of the Universities and that it should be fostered and supported by grants of money from the Dominion Treasury directly to them.

It must be remembered, however, that the functions of the Universities are primarily educational, and that by the British North America Act matters relating to education are not by any means national in their scope, but as to upkeep, control and direction belong particularly to the individual Provinces. The Universities as I have stated are especially concerned with the literary, scientific, technical and artistic training of our young men and women. It is true, generally speaking, that the best and most efficient teachers are those who carry on investigative work or direct researches. Such activities give life and vigour to the teaching and serve as a great inspiration to the students. It is also true, however, that the educational aspect of university work imposes definite limits both as to the time available for research and to the character of the researches, especially the experimental ones, which can be undertaken with reasonable prospects of a successful issue. In Universities the problems attacked are generally speaking of fundamental or academic interest. They are such as can be solved by work carried on at intervals, or such, especially those in which students co-operate, as can through their results be used for the attainment of academic standing or the acquisition of University degrees. Problems of a secret or private nature cannot be conveniently worked out in University Laboratories. In the first place it is difficult to maintain secrecy in such institutions, and in the second place the solution of secret problems in University Laboratories is not desirable on account of the lack of harmony in the staff which it is likely to engender, and on account of the need therein for a high minded and lofty scientific spirit which it would inevitably tend to suppress or at least fail to develop.

Moreover it is doubtful if in a democracy such as our own, public funds should be used either directly or indirectly for work of this character. At the same time there seems to be no reason why the Dominion Government should not subsidise research work by grants made directly to members of the staffs of the Universities for researches which are of a public character and are for the public good. Such researches could, with the approval of the authorities concerned, be carried out in University laboratories, for with the conditions at present existing, these and the apparatus in them, are available for a considerable time each year. It would seem to be desirable and advisable in the interests of efficiency to use them. Research work of a secret nature or for the advantage of individual firms, might possibly be tolerated in University laboratories for a time, until other facilities are provided, but in my opinion it should

not be formally encouraged. Experience has shown that there are other agencies through which such work can be more efficiently and satisfactorily carried out.

INDUSTRIAL AND SCIENTIFIC RESEARCH COMMISSION.

In Great Britain where they are now deeply concerned with this question, they established two years ago a Commission on Industrial and Scientific Research*. It is controlled by a Committee of the Privy Council consisting of three or four members of the Government, and directed by an Advisory Council consisting of a small group of men of distinction in Science and of accomplishment in the industries. In Canada through the initiative action of the Minister of Trade and Commerce, Sir George E. Foster, steps have been taken to set up a Commission† of a similar character. It appears that such a body is the best agency for handling the problem with us. Among its activities it will first of all make a survey of the ground for the purpose of seeing what organisations are at present in operation and engaged in research work. It will be the duty of the Commission to co-ordinate these and to extend and develop their efforts. Cognisance will have to be taken by the Commission not only of the work done by the Universities but also of that done through such agencies as the National and Provincial Governmental Departments, the Royal Society, the Royal Canadian Institute the Society for Chemical Industry and perhaps what is most important of all by private firms in their works. The Commission will be able to give definiteness and direction to the efforts now being put forth in this direction by the Boards of Trade, the Grain Growers Association and the Canadian Manufacturers' Association. Machinery will have to be devised to prevent overlapping. Steps will have to be taken to establish in Ottawa, and probably also in such industrial centres as Montreal, Toronto, and Winnipeg, large and fully equipped technical libraries which will contain all Scientific and Technical Journals, Trade and Industrial Magazines, books, and other publications, and also copies of all patents with their specifications wherever issued. We are sadly lacking in such facilities at the present time in Canada and the Commission should take steps to see that this defect is speedily remedied.

In Great Britain a large number of the industries have shown extraordinary enterprise and resourcefulness since the war broke out and there has appeared a greater disposition among individual manufacturers to co-operate by interchanging ideas, putting their trade secrets into the common stock, and calling in all the available scientific and mechanical resources of the country for the purpose of increasing output and improving organisation. In certain trades the changes which

*See Appendices I and II.
†See Appendix IV.

have already taken place amount to a positive revolution. There is scarcely an industry in the country which has not come out of the ordeal of the war without being stimulated by the special difficulties which had to be surmounted. As has been stated, the history of the war in Great Britain has been a history of grave and threatening difficulties courageously faced and successfully overcome.

When the war broke out the manufacture of optical and chemical glass in France and England was practically insignificant. The steel industry was paralysed at first by the lack of chemical glass for testing purposes, and the porcelain and pottery industries were brought to a standstill through the supply from Germany being cut off of Seger cones used as guides to firing. To-day Britain has industries which supply all her needs. The compositions of chemical glasses have been ascertained. Methods of manufacture have been devised and have been put into operation, and through the efforts of Dr. Mellor, recently deceased, the composition of Seger cones has been successfully worked out. The manufacturers of porcelain have pooled their knowledge, combinations have been effected and research laboratories have been instituted and manned to help them through the co-operation of the Industrial Research Commission, and with the aid of the financial support of the Government.

I may perhaps be permitted to refer to another phase of the work of the British Commission on Industrial and Scientific Research. In the report which has just been issued emphasis is laid on what are called "key" or master industries. Such, it is pointed out, are the magneto industry, and the manufacture of lathes and milling machines, optical glass, porcelain, fine chemicals, dye stuffs, synthetic drugs and high explosives. For such articles the market is a limited one but the articles themselves are vital for numerous other industries. For the development of such industries the Commission takes the view that State support is absolutely necessary, and steps have already been taken by that body to place a number of these industries upon a satisfactory basis. Through the action of the Commission* the University of Leeds has made arrangements whereby the organisation known as "British Dyes" may receive substantial assistance in the matter of scientific research and at the same time special facilities are to be given to private firms and others in the national interest. In dealing with the textile industry, support has also been given for the investigation of the nature and constitution of cellulose fibres at the School of Technology at Manchester. The Commission is also supporting an investigation of the de-gumming of silk at the Imperial Institute of Science in London. At the Royal Technical College, Glasgow, and at the University of Manchester it is carrying on researches on the design of steam nozzles for turbines.

*See Appendix III.

As a result of all these activities two tendencies have been emphasised: (1) Trade associations have been formed for common action at home and abroad raising the average standard of production, and (2) recognition has been made of the lee-way they had to make up as regards scientific research, the utilisation of its results and its application to technical and industrial purposes.

The Commission to which I have already referred has been a most potent factor in stimulating and promoting all these results. It has encouraged manufacturers of particular lines to combine in their efforts, it has co-operated by supplying them with information as to the technique of their industries and it has furnished a supply of scientific men likely to help them in the solution of their problems.

WORKS RESEARCH LABORATORIES.

In addition to drawing lessons from what has been accomplished in Great Britain, much may be learned also from what is going on to the south of us. In such large organisations as The General Electric Co., of Schenectady, The Westinghouse Electric and Manufacturing Co., of East Pittsburg., The Eastman Kodak Co., of Rochester, The DuPont Powder Co., The American Rolling Mills Co., The National Electric Lamp Association, The General Chemical Co., The U.S. Steel Corporation, The Edison Laboratories, The Pennsylvania R.R., there are as adjuncts large and magnificently equipped research laboratories manned by the ablest scientific men whose services can be secured and hundreds of thousands of dollars are set apart by each of these organisations every year for industrial research.

In a number of these laboratories the activities of the researchers are not confined to the solution of problems of pressing necessity. In the laboratory of the General Electric Co., for example, the workers are encouraged to exploit fields of purely scientific interest, for it is realised that what to-day may be of merely academic interest may to-morrow have the greatest industrial importance. It is to the credit of this policy that to-day we have on the market the metallic filament electric lamp, the gas filled electric lamp, the gas arc electric lamp, gas electric rectifiers, the Coolidge X-ray tube, and the steel alloys of vanadium and other rare metals which have proved themselves so useful in the manufacture of dental and high speed mechanical cutting tools. .

In Canada our works are as yet, generally speaking, small and limited in their production. We have, however, industries such as the rubber industry, the agricultural implement industry, the cyanamide works, and the steel industry in which a beginning has been made. All these now have research laboratories attached to their works. The

Canadian Pacific Railway, too, has recently recognised the importance of this subject and has organised in connection with its system a development branch under the direction of Messrs. The Arthur D. Little Co., for the purpose of exploiting the natural resources and raw materials with which it is more immediately concerned.

These few illustrations which I have cited and to which others might be added will serve to show what steps are being taken in Great Britain and in the United States to conserve their resources and to stimulate and protect their industries. Moreover they point out very clearly the path which we must follow if our manufacturing interests are to be so protected and developed that they may be prepared adequately to take their part in the great industrial struggle which must inevitably follow the termination of the war.

In Canada as in Great Britain it will be difficult for an Industrial Commission of the kind I have referred to, to deal with individual firms. Small manufacturers cannot afford to set up research laboratories as adjuncts to their works. It will be necessary for the manufacturers in particular industries to combine for scientific purposes and possibly also for financial reasons. For by such action it will be possible for the Government to subsidise research in particular industries. Generally speaking it will not be found practicable, I venture to think, for such subventions to be given to individual firms for the development of research problems of an exclusive or private nature. This will of course lead to the creation of great trusts as it has already done in the United States, but such a result need not necessarily prove an economic evil if we profit by the lessons they have learned and if due precautions are taken for the protection of the interests of labour on the one hand and of those of the consumer on the other.

We must encourage in every possible way our manufacturers to call to their aid the assistance of the trained investigators which we are at present turning out in large numbers in our Universities. We in the Universities are justly proud of the product of our industry and our only regret is that hitherto our industries have failed to avail themselves of the services of the highly trained men and women who graduate from our halls each year. To our regret and to the oft expressed regret of these graduates the lack of openings in our own country has forced them to accept positions in the research laboratories of the United States. There they are assisting in building up great industries, rivals to our own, and in adding to the already stupendous wealth of that great country. This tide is draining us of our most valuable product and we anxiously look forward to the time when the full appreciation of research work and of the application of scientific methods will lead our manu-

facturers to so orientate their industries that an efficient research spirit will prevail. May the time soon come when the mental capabilities of our people as well as the other natural resources of our richly endowed country will be carefully conserved and developed for our own use.

STANDARDISING, TESTING, AND RESEARCH LABORATORIES.

In what has preceded I have dealt with the part which may very well be taken by our Universities in a national scheme of Industrial Research. I have also emphasised what appears to me to be a most important factor in the development of our industries, namely, combination of effort and the establishment of research laboratories in connection with the works of these industries. I have also pointed out in what way it appears to me the Dominion Government may legitimately be asked to give financial aid to these two types of organisation. There is however another phase of the question which demands consideration. In a number of the Departments of Government research work is being carried on continually and entirely for departmental purposes. It is felt by some that there is a danger of overlapping in this work unless some scheme of efficient co-ordination be devised. This matter is now I believe under consideration by those immediately concerned with it, and it is possible that as a result, it may be found necessary to establish in different localities in Canada laboratories in which much of this work can be done under one or more directing bodies, consisting of the permanent officials interested in the matters taken up, and of others whose scientific attainments and qualifications may be such as to make them desirable members of such body or bodies. Departmental activities which might be cited as being pre-eminently suitable for being carried on by such organisations, are, the standardisation of weights and measures, the calibration and testing of meters and measuring instruments of all kinds, the testing of food-stuffs, the analysis of drugs and chemicals, the development of ceramics, the investigation of marine lighting and signalling, the treatment of ores and the investigation of the properties and treatment of natural products such as fish, oils, natural gases, peats and minerals of all kinds.

The working out of a scheme which will embrace all these different types of activity will be a task which, I think you will agree, will tax the powers and capabilities of the Commission on Industrial Research to which I have alluded. It can however be done and effected very speedily if there be a general recognition of the difficulties involved, and if a general and hearty desire be evinced by those whose co-operation is sought to assist in working it out.

It may be said that much of the research work to which I have referred can be accomplished in the laboratories of our Universities. That some of it can I will readily admit, but I venture to think that if a serious attempt be made to meet the needs of our country in an adequate manner, it will be found that University organisations possess limitations, in the way of space requirements, continuity of effort and administrative machinery which effectually preclude them from assuming the direction of anything more than a minor part of the industrial research work of the country.

What is wanted is in my opinion first of all a consolidation and correlation of the research work now being carried out at Ottawa in different departments and under different Ministers.

In my opinion the magnificent work which is now being done in the Department of Mines at Ottawa, could very well be extended. Increased laboratory accommodation should be provided and additions made to the staff of highly trained technical experts. The sections in which problems of a physical and chemical nature can be treated should also be expanded. Problems of this type are now being dealt with by a number of the Governmental Departments at Ottawa, but in my opinion all these activities should be co-ordinated with the work referred to above, and the whole placed under the direction of one Board, embracing the highest technical and scientific opinion available in the country. If such consolidation were accomplished it could be done on a basis and in a manner to provide for the most powerful and the most efficient scientific direction.

In the second place I think the facilities afforded by the Universities should be supplemented by the establishment of a few physical and chemical Research Bureaus or Laboratories in the centre of those localities in Canada where industrial activity is greatest. For example, under the conditions at present existing it would seem that one of such Bureaus could with advantage be established in the Province of Quebec, either at Montreal or Quebec—preferably at Montreal. Another should be established at Toronto, probably a third at Winnipeg, and later on a fourth in British Columbia, and maybe a fifth at some centre in the Eastern Provinces. These Bureaus supplementing the facilities offered by the Universities could be made somewhat elastic in their organisation and they could become most efficient institutions for assisting the departments of Provincial Governments in their scientific work, and for co-operating with manufacturers by providing them with scientific information and advice and by investigating for them numerous scientific problems which are pressing for solution.

III. BUREAU OF INDUSTRIAL RESEARCH OF THE ROYAL CANADIAN INSTITUTE.

And now I may be asked what part does the Royal Canadian Institute aim at taking in the scheme of National Industrial Research which I have briefly outlined. In a sentence it aims at providing local effort to meet local needs.

The Royal Canadian Institute was incorporated by a Royal Charter granted on the 4th of November, 1851. Its aims are:

I. To promote scientific research in Canada. For this purpose it encourages all who are workers in Science to present to the public through its meetings the results of their investigations and it offers to them every facility for making these known through the Proceedings and the Transactions which immediately on publication are sent to upwards of five hundred scientific learned societies throughout the world.

II. To form in Canada a library of the publications of all the scientific societies of the world. These publications are given in exchange for the Proceedings and Transactions of the Royal Canadian Institute and as this exchange has been going on for upwards of sixty five years the Institute has in consequence a library of about 10,000 volumes composed of the scientific memoirs and archives of all the important learned societies. This library is the only one of its kind in Canada and it has already proved of very great value to workers in Science.

III. To engage and lead the attention of the people to questions of public interest and utility on which scientific opinion may have an important bearing and

IV. To bring into co-operation all the scientific workers in Canada. The institute endeavours to accomplish this by offering assistance in the way of publication of valuable papers of scientific workers and by placing at their service the library of the Institute. But the aims of the Royal Canadian Institute are higher still for it recognised that from economical and geographical considerations the Western portion of Ontario including the city of Toronto and its associated contributary districts is marked out as a region of intense prospective industrial activity. Its numerous railways, existent and projected, both steam driven and electric, together with its vast available resources in electric power, indicate very clearly that it is peculiarly well suited for the location of numerous and extensive industries. These industries will require scientific guidance and advice, and an organised scientific basis for the economical production and manufacture of their products.

To meet this situation the Royal Canadian Institute, some two years ago, organised a "Bureau of Industrial Research and School of Specific Industries" and with this organisation it aims at promoting in every way available the alliance between science and industry and the advancement of original Scientific and Industrial Research in Canada. It aims at undertaking to report upon the bibliography of any scientific subject or the object of any Scientific and Industrial Research. In a word it aims at taking from Industrialists perplexing manufacturing problems and by the application thereto of contemporary Science, working out practical commercial solutions of these problems.

On the Council of the Bureau we have representatives from the staff of all the Faculties in the University of Toronto, we have representatives from the Technical Institute, the Canadian Manufacturers' Association, the Board of Trade of Toronto and of the Associated Boards of Trade of Ontario. The Society of Chemical Industry also has representatives on the Council. Moreover we are assured, I am told, of the hearty support of practically all of those members of the staff of the University who may not for the time being be members of the Council. I have no doubt, too, that in the course of time the Council will include representatives from the various departments of the Provincial Government and of the Trades and Labour Council. It is gratifying to find that at its inception the Bureau has secured the hearty support of such influential bodies as I have mentioned. It means that many preliminary difficulties have been successfully overcome and that we can now move forward united and confident of the ultimate success of the local movement.

Among other directions in which the Bureau intends to act, it aims as mentioned above, at working out an information department. It is thought that such a department can first of all encourage the manufacturers to apply to the Bureau for information on the technique of specific industries. It is our opinion too that surveys should be made from time to time of our industries by the Bureau with a view to collating information regarding the character and extent of their mechanical equipment. Furnished by them with this information it will be possible to make suggestions for increasing production and for embarking on the manufacture of new products. We have in the Royal Canadian Institute as I have stated the basis of a good technical library. We have, too, the Toronto Public Reference Library, the University Library, and the Provincial Library in close proximity. But the technical side of all these libraries could be greatly extended. I venture to think that this is a direction in which we would be warranted in applying to the Dominion Treasury for financial assistance. An information depart-

ment such as I have referred to and a large fully equipped technical library would soon prove of inestimable value to the manufacturers in the districts I have mentioned, and to the public generally. There should I think, be at least three or four of such libraries established in Canada and it seems to me that for the Western and Central Ontario Districts it should be done by building upon the basis which has been so well laid, *i.e.*, by adding to and extending the library of our Institute.

I think, too, that the Government of the Province of Ontario might increase its support of the movement inaugurated by the Royal Canadian Institute by coming into closer relation with the Bureau. Many of the problems which are presented to the departments of the local Government for solution could be solved in the laboratories of the Provincial University, but there are others which require continuity of effort and sustained treatment. Numbers of these would require special research apparatus, more space than is available or is likely to be available in University laboratories, and a special staff of researchers. Such problems could with economy and efficiency be investigated in the laboratories of the Bureau of Industrial Research associated with the Institute. I would urge the members of the Provincial Government to give consideration to the suggestion that in the steps I understand they contemplate taking to develop research in connection with their own departments they could possibly accomplish efficiently what they are aiming at by co-ordinating their efforts with those now being put forth by the Institute in a parallel direction.

RESEARCH WORK AND THE INDIVIDUAL MANUFACTURER.

I have now referred to the types of investigations, which according to my judgment can best be carried out in our University Laboratories, in the works of our industries and in laboratories which may very well be established at the different industrial centres in our country. But as yet I have left out of consideration the means of attempting the solution of problems of a private and exclusive or secret nature. These I think belong to a category by themselves. The cost of defraying the expenses incurred in solving such problems should I think be met by the manufacturers themselves, who are to be directly benefitted by their solution. Distinct laboratory equipment will be required for the purpose and this the Bureau of the Royal Canadian Institute aims at providing if it can succeed in securing adequate financial support. I would appeal to our manufacturers for help in this matter. Many of them, through their own energy and resourcefulness, through beneficent tariff arrangements, and through other favourable conditions, have

become prosperous, and even wealthy. Will not some one or some group of them come forward and give their support to the equipment of such an institution? It need not be large, it need not be costly, but one of some kind is required if we are to attempt the work at all. The Mellon Institute which has been founded at Pittsburg by private benefaction is our model in this direction. Through the energy of the late Professor R. K. Duncan, a Canadian, and through that of his successor Dr. Bacon and of his colleagues numerous problems have been solved in the Mellon Institute which have enabled the manufacturers of the United States to increase their output and lower the cost of production.

Among the problems successfully treated in the Mellon Institute are (1) the refining of copper, (2) the process of leaching, (3) cement manufacture, (4) the elimination of the smoke nuisance, (5) glass manufacture, (6) bread making, and (7) paper making.

With these illustrations before us it is clear that we can follow with confidence in the footsteps of those who founded the Mellon Institute for they have marked out a path which has led and will continue to lead to certain success.

I have spoken thus definitely about a sphere of activity which might legitimately be developed by the Bureau of the Royal Canadian Institute. It is a field which as yet has not been pre-empted by any interests or by any existing scientific organisations. There is no need, however, for the Bureau to confine its attention to the manufacturers in one particular part of Ontario. The Institute is founded on a Royal Charter and its constitution is not by any means limited by Provincial considerations. The whole of Canada is open to it. We must of course, develop slowly, but in the course of time problems of the type I have indicated will be presented for solution in all parts of our country and there is no reason why the Bureau should not co-operate in helping manufacturers no matter in what part of Canada their industries may be located.

As the situation develops, too, problems whose solutions are in the general public interest will multiply, and the Bureau as well as our universities may very well concern itself with the solution of such problems in addition to those of an exclusive or private nature. I venture to think, however, that frequently it will be found that our Universities and Technical Institutes will be able to provide experimental equipment and to afford laboratory facilities better suited for work of general interest than the Institute. For the handling of such cases I am assured that our Universities and Technical Institutes will heartily co-operate with the Institute in making such official arrangements as will enable us to hand over the solution of problems of a public nature to the directors

of the laboratories in these institutions either for direct solution by them or for the investigative work to be immediately initiated, directed, supervised, and administered by them.

IV. RESEARCH WORKERS.

I should also like to refer with your permission to one or two other matters which to me appear to merit some attention in the treatment of my subject. One of these has to do with the welfare of the personnel required to actually carry out the investigations of industrial research. We have in the graduates who are being turned out annually from our universities a body of well trained investigators. In the past, as already pointed out, many of these have had to go to the United States for employment. We should, however, retain them in our own country. They could be secured and held, initially and in part at least, by the establishment, in connection with our Bureau, of Fellowships of about $1500 per annum. This is a modest sum and one which could be easily paid by manufacturers for the solution, either complete or in part, of some of their problems. I hope this matter will te taken up at once, that the manufacturers will immediately take steps to enable us to secure modest but suitable laboratory accommodation, and that they will hasten to bring their difficulties to us and endow Fellowships for their solution. We on our side are waiting to co-operate most heartily. Another point to which I must refer is the treatment of Fellows who succeed in successfully solving problems which may be presented. They should not be treated in a niggardly manner. Many of them are looking to the industries for their future occupation. If they make some new discovery or improve a process, they should receive some adequate financial return. The manufacturers should be prepared to adopt some system of paying royalties to them, or what is better still, they should be given some financial interest in the firm which profits by their discovery or improvement in a process. While this would be only fair it would also tend to put our industries on a higher plane for it would be putting into operation a scheme which would ultimately result in our great industries being directed and managed by a body of men who have received not only the highest training which our Universities and Technical Colleges can furnish, but who have also shown that they possess the power to initiate and carry on original investigations, and at the same time have a deep sympathy with research methods and know how to co-ordinate these with economic values.

V. INDUSTRIAL ACTIVITY AFTER THE WAR.

Another matter to which I wish to draw your attention is the utilisation of our war equipment in the industries after the war. The prosecution of the war has necessitated both in this country and in Great Britain, the establishment of vast and extensive works for the manufacture of munitions and other war equipment. It has necessitated also the installation of enormous additions to the mechanical equipment of existing works. Two years ago for example the manufacture of aeroplanes and aircraft generally was but an insignificant industry in Great Britain. To-day all is changed. At the present time aircraft are being constructed in a dozen centres in England and Scotland, and in addition the Government maintain a factory at Farnborough which covers hundreds of acres and includes on its staff thousands of men and women who are feverishly at work constructing and assembling the parts of aeroplanes which are being turned out in prodigious numbers. Great and enormous works have also been established for the manufacture of chemicals and other materials used in the making of explosives and of artillery. Formerly the guns and ammunition for the army were largely manufactured at Woolwich but to-day there is hardly a town or city in the Kingdom which is not contributing its quota to the armament of the nation. In one part of Scotland alone which came under my notice, the works recently established by the Government for the manufacture and storage of explosives and other munitions covers an area of almost 200 square miles.

On the Clyde, too, the most intense activity prevails. An entirely new fleet is being created. In a visit I paid there recently I counted over two hundred war vessels under construction. There were flotillas of torpedo-destroyers, and destroyer leaders, dozens of submarines, many mine sweepers and monitors, and numbers of battle cruisers and battle ships. Yards in which a war vessel had never been constructed hitherto had their slips filled with these additions to the navy. Firms which were formerly competitors now lend one another engineers, models, drawings and workmen. In addition to the need for this enormous expenditure of strength on the construction of war ships there came an imperative demand for increased merchant tonnage. To this demand the workers on the Clyde, masters and men, responded with alacrity and enthusiasm and the intensity of the effort is most impressive. In addition to the war vessels now being built which I have mentioned I observed large numbers of enormous freight and passenger carrying vessels under construction, some almost completed and others with their keels only just laid. As one passes up the Clyde from the Broomielaw to Greenock

in a small river boat one is deafened with the noise and the rattle of it all. It is simply stupendous and gives one the impression of being in the midst of a gigantic factory where the workers are not men but supermen and the directors are the very gods and titans of mythology. And the intensity of the effort is not confined to the Clyde district alone for if one is to believe what one hears, a similarly intense activity is in evidence in the neighbourhoods of Portsmouth, Chatham, Newcastle, Liverpool and Belfast.

The changes which have come about in the last two years in the British Isles are beyond expression. Enormously more has been accomplished than could have been believed possible even by the most vivid imagination. We have seen the Empire perform the greatest achievement in history in raising over five million volunteer soldiers within two years and in creating the arms, munitions and equipment necessary for that army. What is more wonderful still is that we have seen great changes wrought in the mental outlook and viewpoint of the British people.

We have seen them when confronted with the grave and threatening difficulties of this tremendous ordeal, suddenly give up their lives of indulgence, luxury and ease and mobilize all their financial, intellectual, and industrial strength for the struggle. We have seen the labour interests assume national responsibilities, to a degree far beyond what previous to the war we had thought possible. The part taken by the women in this movement, too, is beyond all praise. In the British Isles as also in a measure in Canada one to two millions of women have for the first time received the mental and physical development which comes from earning money and from training in work. Millions of men and youths have advanced from unimportant common place labour to skilled work. At the end of the war we shall have in the Empire from four to five millions of trained men, survivors from the battlefields who will have had the tremendous advantage derived from the physical, mental and moral training required of soldiers. Through the efforts of the clergy, our military leaders and our statesmen, the national conscience, too, has been so awakened that a revolution has been accomplished in the attitude of the army and of the manhood of the nation generally, towards questions of temperance, clean living, literature and the drama. I am making but a conservative estimate when I say that as a result of the war from 10 to 15 millions of the British people will have made an enormous mental, moral, and physical advance.

In walking through the different works in the cities of London, Manchester, Liverpool, Birmingham and other places one is struck by a new alertness, a sort of mental and physical exhilaration that gives

one the impression of being in the midst of a gigantic struggle in which the participants have consecrated themselves body and soul, with a lofty cheerfulness and transcendent eagerness to the accomplishment and consummation of one of the noblest and most stupendous tasks to which humanity has ever set its hand.

On the breaking out of the war two years ago, one witnessed the most heart-rending sights when trainloads of soldiers left the great stations in the British Isles for the front. Wives were seen clinging to husbands, mothers to sons, and sweethearts to their lovers. The air was filled with wailing and anguished cries. To-day, under similar circumstances, one still sees women and girls crowding the railway stations to bid good-bye to their soldier sweethearts and relatives. But all is changed. There is still eagerness, yearning, longing, admiration and tenderness in their faces, but practically no tears. The people are beyond tears. The effects of the war are everywhere and are felt equally by all classes. The result is a most remarkable mental, moral and spiritual exaltation. I have not had the privilege of visiting France since the war began, but I am told that the changes which have taken place in that wonderful country are equally marked and equally profound. It has been truly said that "Britain and France are not simply renewed—they are reborn. The British Empire and France are the youngest nations in the world".

The changes which have been wrought by the war in the Old World have also been going on in Canada, though to a less degree, and the question naturally arises:—What are we to do with all this enormous quantity of mechanical equipment which has been assembled and what are we to do with the millions of men and women who have received this remarkable stimulation and change of outlook from the stress of war? Assuredly here we have a problem which will tax the resources of Governments and Legislatures let alone that of Industrial Commissions.

We must however remember that the mechanical equipment, and mental energy which has been developed in the process of rescuing the Empire from disaster, can also be used in the arts of peace for maintaining and extending its intellectual and industrial supremacy. Both capital and labour have learned how to respect each other. Capital has learned that the labourer is worthy of his hire, and labour has learned that the promotion of its interests is not incompatible with efforts on the part of capital to increase production. Both have learned the value of the application of scientific principles to industry and have seen more clearly that co-operation and mutual confidence are vital factors in the advancement of national greatness.

With a successful termination to the war fairly well in sight, increasing attention is now being paid both in Canada and in Great Britain to this question and in both portions of the Empire steps have been taken to constitute advisory boards whose function will be to indicate to manufacturers the various industries in which their war equipment can be put to profitable use. France is probably at the present time ahead of us in dealing with this question for in a report which has recently been published in that country some interesting, definite and very helpful suggestions are made. In this report, for example, it is pointed out that the equipment which is now being used for the manufacture of acids, tar products, powder, and explosives, can under peace conditions be used for the manufacture of artificial perfumes, photographic materials, pharmaceutical products and organic and inorganic dyes. It is also shown that engineers and workmen who have been trained in the manufacture of smokeless powder, melinite, and trinitrotoluol can after the war be used in the same works and with the same machinery to manufacture such articles as artificial silk, nitrobenzine, aniline, etc.

The report also goes on to say that in order to give effect to these suggestions, there has been formed in France the Syndicat National de Matières Colorantes, which is a combination of coal and metallurgical companies, paper makers, dyers, textile manufacturers, etc. This illustration will serve to indicate to you the progress of the movement in France. Thanks to it, it is now clear that hundreds of thousands of workmen in that country will continue to earn their wages and the works which are to-day mobilised for destruction will to-morrow, when peace is declared, make France more powerful than ever.

One hears frequent reference made these days to the transference of enormous reserves of accumulated wealth from the British Empire and the allied countries to neutral nations, especially the United States, and one is apt to be discouraged by the vastness of our debt to that nation incurred through our prosecution of the war. We must realise however that the future is not at all a hopeless one. Our greatest loss is that of the lives of thousands of our bravest and best whom we can ill spare, but who have made the supreme sacrifice gladly, and confident that by so doing they were not contributing to the loss but to the enhancement of the greatness and glory of our Empire. These precious lives can never be restored to us. But the accumulation of vast mechanical equipment, the establishment of enormous works of all kinds, the mobilisation of industry, practice in the successful production of all types of manufacture in enormous quantities, tremendous advances in the manipulative and mechanical skill of millions of our people, and a recognition of the vital

necessity of co-operation between science, industry, labour, finance, and government—these, together with the wider outlook, the intensity of effort, the moral uplifting and the spiritual exaltation which the war has brought to us in its train are all assets which in themselves connote national greatness. If we conserve and cherish these, if we stimulate and foster the scientific spirit in our midst, if our industries more and more continue to look to science for direction, information and advice, national indebtedness will gradually pass away and with the memory of the sacrifices we have made and the efforts we have put forth, for the liberation, peace and happiness of humanity ever before us, our Empire will rise purified and ennobled to an enhanced glory far beyond that which, in the past, with good reason, has been its chief pride and most cherished possession.

FINANCIAL AND GOVERNMENTAL SUPPORT OF KEY INDUSTRIES.

Had time permitted I could have referred here at some length to a part banking interests might play in developing certain types of manufacture in this country which are at present lacking. I refer to the lack of manufacturers of such articles as glass tubing, thermometers, chemical glass ware, porcelain ware, meters of all kinds, certain types of technical apparatus, certain chemicals, gauges, dies, and machine tools. In the industries these articles are of a fundamental nature and are of vital necessity. In the past our supply was largely drawn from the United States, Great Britain, France or Germany. This means that much of the manufacturing and many of the researches in the works, in the Universities, and the Colleges, are frequently held up for months at a time, Such articles would in Canada at first be manufactured in a small way, at least until types were developed which would command the market in foreign countries. Those who engage in the manufacture of articles having a limited market would probably find it difficult to get proper financial support from our banking institutions. It is quite easy in Canada apparently for railroads, electric development companies, steel corporations, milling and other large and politically powerful interests to have very large advances made to them by the banks under legislative or governmental guarantees, but it is not so easy for the manufacturers of such articles as I have mentioned to get it. It is of great national interest however to have these industries in our midst, and it appears to me that if a Dominion Commission on Industrial Research would emphasise the necessity of developing these fundamental industries in our country that the Government would soon take such legislative action as would induce our banking and financial institutions

to single out these vital industries as being for the common good, worthy of very special support and encouragement. It seems to me that if it be necessary to continue a policy of "protection" in this country—and I may add that it seems to be both desirable and necessary—we should see to it that it is first of all applied to those industries which are basic and of vital importance to the community rather than to those for example which have to do with the preparation of foodstuffs and clothing material, and the production of books, periodicals and printed matter generally. In the past the application of the principle of "protection" has in some cases worked out as the imposition of a special tax upon the consumer for the benefit of the manufacturer without producing any compensating general advantages in the way of a commensurate or even substantial contribution to the wealth of the nation. I venture to present a special plea at this time, for a scientific revision of our tariffs. Let us take stock of our economic position in a broad way, and adopt such measures as will tend to lower the cost of living and as will ensure the production and manufacture in our own country of such articles as are of vital and fundamental importance to the nation. We are frequently told that the manufacture of machine tools and other articles belonging to the category I have mentioned will require a class of skilled labour which has not in the past been available. In the future this argument cannot be put forward for as a result of the war we shall have hundreds and thousands of men and women in the empire who have had a training not only in machine and tool work of the highest precision but also in machine construction and machine design. The higher positions in such manufacturing industries will afford openings for the trained technical experts being turned out by our Universities. Let us see to it that in Canada we are ready to use to the full the magnificent contribution to our national capabilities which the stress of war has made.

THE HOUSING PROBLEM.

One more point and then I have done. In a previous part of the paper I have referred to the prospective development of the Western part of Ontario and particularly the Niagara Peninsula into a region of intense industrial activity. This means that unless care is taken in advance we shall have in this district a repetition of the wretched conditions which prevail in the neighbourhood of such places as Sheffield, Leeds, Glasgow, and other manufacturing cities in the Old Country. In fact the evil is to a certain extent already with us for if one visits certain towns in Ontario and other parts of Canada at the present time one will find that the workmen are housed in buildings entirely lacking

in architectural beauty, situated often on low-lying and otherwise most unsuitable ground areas. Too often no serious attempt is made to lay out the streets with taste or to erect the houses with due provision for a reasonable amount of comfort and sanitary safeguards. They often seem to be erected at haphazard in close proximity to the works, and in the midst of an atmosphere contaminated with grime and smoke. Very little provision is made for open spaces, garden facilities and park areas. The matter is left entirely to the whim of the manufacturer and the machinations of the land speculator.

The proper housing of workmen should, I venture to say, be as much the concern of Boards of Health as the disposal of sewage or the provision of a supply of pure water. If due care be taken now by adequate legislative action we can easily see to it that at a very small additional cost homes can be provided for our workmen pleasing in design, artistically located in healthy locations, and with properly laid out areas for garden and recreation purposes which will give the moral and aesthetic natures of our working people a legitimate chance of development.

Our water supplies in Western Ontario will also have to be looked after. At the present time these are drawn for practically all the towns in this district from sources which in the near future cannot fail to become contaminated. In the Georgian Bay and Lake Huron we have an inexhaustible supply of pure water. With this as a source it would seem to be quite a simple engineering problem to erect reservoirs on the height of land in the counties of Perth and Waterloo, Wellington, or Dufferin, which would supply the whole of Western Ontario. If this were done the pumping plants in all the cities and towns in the district could be dispensed with, and one plant of suitable dimensions, if properly located, would suffice for all. We have seen how in England and Scotland vast sums of money have been expended and how great physical difficulties have been overcome to furnish the cities of Glasgow, Liverpool, Manchester, Sheffield, Birmingham and London with a plentiful supply of pure water. In Western Ontario the problem would I venture to think, be a comparatively simple one to solve. It would however require to be dealt with in a broad way, but with the example of the successful development of the Provincial Hydro-electric scheme before us, it is a problem which our different municipalities, towns and cities might readily undertake to consider, confident that a satisfactory and yet simple solution can readily be found.

But I must close my remarks.

In what has preceded I have endeavoured to present a few aspects of the question of industrial research as they appear to me. My treatment must necessarily be inadequate and defective. I have not had the

opportunity, except to a very limited extent, of becoming familiar either with the financial, the mechanical, or the economic side of manufacturing. My calling, however, leads me continually to the consideration of scientific problems and scientific methods. I have in a measure become familiar with the steps taken in Great Britain and other countries in developing schemes of industrial research and in dealing with allied matters. These I have endeavoured to apply to what appears to me to be the special needs of our own country, a country which we all agree is full of potentiality and promise.

In closing may I be permitted to remind you that the terrible War which is now being waged is but one aspect of a tremendous struggle for Truth and Righteousness. Let us not forget that it is a struggle in which Science is one of the combatants. Are we to be the Allies of Science or must Science look in another direction for support? The words recently penned by the English Poet, William Watson, are not without interest at this time. They are entitled:

WHAT SCIENCE SAYS TO TRUTH.

As the mainland to the sea
Thou art to me.
Thou standest stable, while against thy feet
I beat, I beat!

Yet from the cliffs so sheer, so tall,
Sands crumble and fall;
And golden grains of thee my tides each day
Carry away.

APPENDIX I.

ORDER IN COUNCIL CONSTITUTING A COMMITTEE OF THE PRIVY COUNCIL OF GREAT BRITAIN AND IRELAND AND AN ADVISORY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH.

AT THE COURT AT BUCKINGHAM PALACE,

The 28th day of July, 1915.

PRESENT:

THE KING'S MOST EXCELLENT MAJESTY IN COUNCIL.

It is this day ordered by His Majesty in Council that the Lord President of the Council, the Chancellor of the Exchequer, the Secretary for Scotland, the President of the Board of Trade, the President of the Board of Education, and the Chief Secretary for Ireland, respectively, for the time being, the Right Honourable Viscount Haldane of Cloan, K.T., O.M., F.R.S., the Right Honourable Arthur Herbert Dyke Acland, and the Right Honourable Joseph Albert Pease, M.P., be, and they are, hereby appointed a Committee to direct, subject to such conditions as the Treasury may from time to time prescribe, the application of any sums of money provided by Parliament for the organisation and development of scientific and industrial research.*

It is further ordered that during His Majesty's pleasure the President of the Board of Education shall preside over the said Committee in the absence of the Lord President:

Moreover, it is further ordered that, for the purposes aforesaid, there shall be an Advisory Council (consisting of such number of persons holding office for such term as the Committee shall from time to time determine) to which shall stand referred, for their report and recommendation, proposals—

(i) for instituting specific researches;

(ii) for establishing or developing special institutions or departments of existing institutions for the scientific study of problems affecting particular industries and trades; and

(iii) for the establishment and award of Research Studentships and Fellowships.

The said Council may itself initiate such proposals and may advise the Committee on such matters, whether general or particular, relating to the advancement of trade and industry by means of scientific research as the Committee from time to time determine.

And it is ordered that the following shall be among the first Members of the Advisory Council:—

Sir William Symington McCormick, LL.D. (Administrative Chairman);
The Right Honourable Lord Rayleigh, O.M., D.C.L., LL.D., F.R.S.;
George Thomas Beilby, Esquire, LL.D., F.R.S.,
William Duddell, Esquire, F.R.S.;
Professor Bertram Hopkinson, F.R.S.;
Professor John Alexander McClelland, F.R.S.;
Professor Raphael Meldola, F.R.S.; and
Richard Threlfall, Esquire, F.R.S.

* By supplemental Order in Council of 23rd May 1916 the Secretary of State for the Colonies for the time being was appointed a member of the Committee.

And it is ordered that the Committee may, out of funds provided by Parliament or otherwise available for the purpose, pay such remuneration to the Members of the Advisory Council and such salary to the Administrative Chairman thereof as the Treasury authorise, and defray to such an amount as may be sanctioned by the Treasury any other expenses incurred by the Council in or in connexion with the performance of its duties, and may enter into any contracts incidental thereto.

And it is ordered that the Committee shall in every year cause to be laid before both Houses of Parliament a Report of their proceedings and of the proceedings of the Advisory Council, during the preceding year.

ALMERIC FITZROY.

APPENDIX II.

SCHEME FOR THE ORGANISATION AND DEVELOPMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH IN GREAT BRITAIN AND IRELAND.

1. There is a strong consensus of opinion among persons engaged both in science and in industry that a special need exists at the present time for new machinery and for additional State assistance in order to promote and organise scientific research with a view especially to its application to trade and industry. It is well known that many of our industries have since the outbreak of war suffered through our inability to produce at home, certain articles and materials required in trade processes, the manufacture of which has become localised abroad, and particularly in Germany, because science has there been more thoroughly and effectively applied to the solution of scientific problems bearing on trade and industry and to the elaboration of economical and improved processes of manufacture. It is impossible to contemplate without considerable apprehension the situation which will arise at the end of the war unless our scientific resources have previously been enlarged and organised to meet it. It appears incontrovertible that if we are to advance or even maintain our industrial position we must as a nation aim at such a development of scientific and industrial research as will place us in a position to expand and strengthen our industries and to compete successfully with the most highly organised of our rivals. The difficulties of advancing on these lines during the war are obvious and are not under-estimated, but we cannot hope to improvise an effective system at the moment when hostilities cease, and unless during the present period we are able to make a substantial advance we shall certainly be unable to do what is necessary in the equally difficult period of reconstruction which will follow the war.

2. The present scheme is designed to established a permanent organisation for the promotion of industrial and scientific research.

It is in no way intended that it should replace or interfere with the arrangements which have been or may be made by the War Office or Admiralty or Minister of Munitions to obtain scientific advice and investigation in connection with the provision of munitions or war. It is, of course, obvious that at the present moment it is essential that the War Office, the Admiralty, and the Ministry of Munitions should continue to make their own direct arrangements with scientific men and institutions with the least possible delay.

3. It is clearly desirable that the scheme should operate over the Kingdom as a whole with as little regard as possible to the Tweed and the Irish Channel. The research done should be for the Kingdom as a whole, and there should be complete liberty to utilise the most effective institutions and investigators available, irrespective of their location in England, Wales, Scotland or Ireland. There must therefore be a single fund for the assistance of research, under a single responsible body.

4. The scheme accordingly provides for the establismhent of—

(*a*) A Committee of the Privy Council responsible for the expenditure of any new moneys provided by Parliament for scientific and industrial research;

(*b*) A small Advisory Council responsible to the Committee of Council and composed mainly of eminent scientific men and men actually engaged in industries dependent upon scientific research.

5. The Committee of Council will consist of the Lord President, the Chancellor of the Exchequer, the Secretary for Scotland, the President of the Board of Trade, the President of the Board of Education (who will be Vice-President of the Committee), the Chief Secretary for Ireland, together with such other Ministers and individual Members of the Council as it may be thought desirable to add.

The first non-official Members of the Committee will be—

The Right Hon. Viscount Haldane of Cloan, O.M., K.T., F.R.S.,
The Right Hon. Arthur H. D. Acland, and
The Right Hon. Joseph A. Pease, M.P.

The President of the Board of Education will answer in the House of Commons for the sub-head on the Vote, which will be accounted for by the Treasury under Class IV., Vote 7, "Scientific Investigations, &c."

It is obvious that the organisation and development of research is a matter which greatly affects the public educational systems of the Kingdom. A great part of all research will necessarily be done in Universities and Colleges which are already aided by the State, and the supply and training of a sufficient number of young persons competent to undertake research can only be secured through the public system of education.

6. The primary functions of the Advisory Council will be to advise the Committee of Council on—

(i) proposals for instituting specific researches;

(ii) proposals for establishing or developing special institutions or departments of existing institutions for the scientific study of problems affecting particular industries and trades;

(iii) the establishment and award of Research Studentships and Fellowships.

The Advisory Council will also be available, if requested, to advise the several Education Departments as to the steps which should be taken for increasing the supply of workers competent to undertake scientific research.

Arrangements will be made by which the Council will keep in close touch with all Government Departments concerned with or interested in scientific research and by which the Council will have regard to the research work which is being done or may be done by the National Physical Laboratory.

7. It is essential that the Advisory Council should act in intimate co-operation with the Royal Society and the existing scientific or professional associations, societies and institutes, as well as with the Universities, Technical Institutions and other institutions in which research is or can be efficiently conducted.

It is proposed to ask the Royal Society and the principal scientific and professional associations, societies and institutes to undertake the function of initiating proposals for the consideration of the Advisory Council, and a regular procedure for inviting and collecting proposals will be established. The Advisory Council will also be at liberty to receive proposals from individuals and themselves to initiate proposals.

All possible means will be used to enlist the interest and secure the co-operation of persons directly engaged in trade and industry.

8. It is contemplated that the Advisory Council will work largely through Sub-Committees reinforced by suitable experts in the particular branch of science or industry concerned. On these Sub-Committees it would be desirable as far as possible to enlist the services of persons actually engaged in scientific trades and manufactures dependent on science.

9. As regards the use or profits of discoveries, the general principle on which grants will be made by the Committee of Council is that discoveries made by institutions, associations, bodies, or individuals in the course of researches aided by public money shall be made available under proper conditions for the public advantage.

10. It is important in order to secure effective working that the Advisory Council should be a small body, but it is recognised that even if full use is made by the Council of its power to work through reinforced Sub-Committees, its membership may be found inadequate to do justice to all the branches of industry in which proposals for research may be made or to the requests of other Government Departments for assistance. It is therefore probable that it will be found necessary to strengthen the Council by appointing additional Members.

The first Members of the Council will be—

The Right Hon. Lord Rayleigh, O.M., F.R.S., LL.D.
Mr. G. T. Beilby, F.R.S., LL.D.
Mr. W. Duddell, F.R.S.
Prof. B. Hopkinson, F.R.S
Prof. J. A. McClelland, F.R.S.
Prof. R. Meldola, F.R.S.
Mr. R. Threlfall, F.R.S.
With Sir William S. McCormick, LL.D., as *administrative Chairman.*

11. The Advisory Council will proceed to frame a scheme or programme for their own guidance in recommending proposals for research and for the guidance of the Committee of Council in allocating such State funds as may be available. This scheme will naturally be designed to operate over some years in advance, and in framing it the Council must necessarily have due regard to the relative urgency of the problems requiring solution, the supply of trained researchers available for particular pieces of research, and the material facilities in the form of laboratories and equipment which are available or can be provided for specific researches. Such a scheme will naturally be elastic and will require modification from year to year; but it is obviously undesirable that the Council should live "from hand to mouth" or work on the principle of "first come first served," and the recommendations (which for the purpose of estimating they will have to make annually to the Committee of Council) should represent progressive instalments of a considered programme and policy. A large part of their work will be that of examining, selecting, combining, and co-ordinating rather than that of originating. One of their chief functions will be the prevention of overlapping between

institutions or individuals engaged in research. They will, on the other hand, be at liberty to initiate proposals and to institute inquiries preliminary to preparing or eliciting proposals for useful research, and in this way they may help to concentrate on problems requiring solution the interest of all persons concerned in the development of all branches of scientific industry.

12. An Annual Report embodying the Report of the Advisory Council will be made to His Majesty by the Committee of Council and laid before Parliament.

13. Office accommodation and staff will be provided for the Committee and Council by the Board of Education.

ARTHUR HENDERSON.

23rd July 1915.

APPENDIX III.

LIST OF RESEARCHES AIDED DURING THE YEAR 1915-16 BY THE COMMITTEE OF THE PRIVY COUNCIL OF GREAT BRITAIN AND IRELAND ON SCIENTIFIC AND INDUSTRIAL RESEARCH.

Research.	Institution or Body responsible for the Research.	Institutions, Laboratories, &c., at which the Research is, or will be, conducted.
(i) RESEARCHES WHICH WERE ALREADY IN PROCESS.		
Laboratory Glass - -	Institute of Chemistry.	Laboratory of the Institute of Chemistry, King's College, London, and Professor Jackson's private laboratory.
Optical Glass - -	Do Do.	Do. do.
Refractory Materials	Institution of Gas Engineers.	Stoke-on-Trent Central School of Science and Technology.
Hardness Test for Journals and Pins.	Institution of Mechanical Engineers.	National Physical Laboratory. Certain firms are co-operating.
Properties and Composition of Alloys.	Do. do.	National Physical Laboratory.
Flow of Steam through Nozzles.	Do. do.	University of Manchester and Glasgow Royal Technical College. Certain firms are co-operating.
Heating of Buried Cables.	Institute of Electrical Engineers.	National Physical Laboratory and University of Liverpool. Certain firms and public electricity supply undertakings are co-operating.
Properties of Insulating Oils.	Do. do.	Manchester Municipal School of Technology. Certain firms are co-operating.
Tool Steel Experiments	Manchester Association of Engineers.	Manchester Municipal School of Technology.
Methods of Notched Bar Impact Testing.	Engineering Standards Committee.	National Physical Laboratory.

Research.	Institution or Body responsible for the Research.	Institutions, Laboratories, &c., at which the Research is, or will be, conducted.
Corrosion of Nonferrous Metals.	Institute of Metals -	University of Liverpool. From 1st October 1916, the research will be transferred to the Royal School of Mines (Imperial College of Science and Technology), and the Brighton Corporation Electric Power Station.
	(ii) NEW RESEARCHES.	
Optical Glass - -	National Physical Laboratory.	National Physical Laboratory.
Glass Technology - -	Sheffield University Delegacy for Glass Research.	Research Institute attached to the University of Sheffield.
Hard Porcelain - -	Joint Research Committee of the Stoke Central School of Science and Technology and the Staffordshire Potteries Manufacturers' Association.	Research Institute attached to the Central School of Science and Technology, Stoke-on-Trent.
Setting and Disintegration of Salts and Crystalline Substances.	Faraday Society - -	Guy's Hospital Medical School and Mr. Bousfield's private laboratory.
De-gumming of Silk -	Silk Association - -	Imperial College of Science and Technology. Certain firms are co-operating.
Tin and Tungsten -	Institution of Mining and Metallurgy.	Royal School of Mines (Imperial College of Science and Technology), privately owned laboratories and concentration works of certain companies owning mines in Cornwall.
Statistical Work in preparation of field for research in Iron and Steel	Iron and Steel Institute	Offices of the Institute.

Research.	Institution or Body responsible for the Research.	Institutions, Laboratories, &c., at which the Research is, or will be, conducted.
Rate of Heat Transmission from Hot Surfaces to Fluids over them.	National Physical Laboratory.	National Physical Laboratory.
Deterioration of Structures of Timber, Metal, and Concrete in Sea Water.	Institution of Civil Engineers.	Various Ports throughout the Empire, and laboratories (for special investigations) as may be required.

APPENDIX IV.

REPORT OF THE COMMITTEE OF THE PRIVY COUNCIL OF THE DOMINION OF CANADA APPROVED BY HIS ROYAL HIGHNESS THE GOVERNOR GENERAL ON THE 6th JUNE 1916

The Committee of the Privy Council have before them a report, dated 23rd May 1916, from the Minister of Trade and Commerce, to whom was referred a despatch from the Right Hon. A. Bonar Law, Secretary of State for the Colonies, calling attention to a scheme of scientific and industrial research for the United Kingdom, as embodied in Parliamentary Paper Cd. 8005, attached hereto, and a copy of the Order in Council approving of the same.

The Minister observes that this scheme, proposed by Mr. Arthur Henderson, contemplated the appointment of a Committee of the Privy Council which should be responsible for the carrying out of the same, and a small Advisory Council responsible to the Committee to be composed mainly of scientific men and men actually engaged in industries dependent upon scientific research. By Order in Council, 28th July 1915, effect was given to this scheme, and the Committee and Council proposed therein were appointed and their respective duties set out. The scheme was to be applied to the United Kingdom as a whole and was not intended in any way to interfere with the arrangements already made by the War Office and the Admiralty in respect to obtaining scientific assistance for the improvement of munitions of war, but was designed to establish a permanent organisation for the promotion of scientific and industrial research.

The Minister observes that after this scheme had gone into operation, suggestions were made from various sources that it should be extended and made applicable to the Overseas Dominions or even to the Empire as a whole. These suggestions were approved in principle by the Committee of Council, and a memorandum was prepared intimating certain preliminary steps that might be taken to bring about gradually co-operation of effort and co-ordination of research throughout the Empire.

On the 20th January 1916 the Minister of Munitions caused to be distributed to educational institutions in the United Kingdom a circular letter inviting co-operation in the improvement and invention of appliances for the prosecution of warfare, and copies of the same were sent to certain universities in Canada. As a result these universities have given full information on the facilities they possess for carrying on research work in respect to the specific purpose of the Minister of Munitions. They express willingness also to co-operate and assist in the work of industrial research, and are of the opinion that some department of the Government of Canada should undertake to co-ordinate and supervise this work and act as a medium of communication.

The Minister desires to point out the urgent necessity of organising, mobilising and encouraging the existing resources of industrial and scientific research in Canada with the purpose of utilising waste products, discovering new processes—mechanical, chemical and metallurgical—and developing into useful adjuncts to industry and commerce the unused natural resources of Canada. At no period has the importance of such united and thorough action been so evident as since the conditions brought about by the war, when the scarcity of certain compounds and processes has caused confusion and paralysis in industries and greatly added to cost of living. Canada has educational and scientific institutions more or less well equipped for conducting this research, which have already done much along their several lines and are willing and anxious to equip

themselves for doing more. There are also private, corporate and Government laboratories, more or less engaged in research work. The Manufacturers' Associations are alive to the importance and absolute necessity of such work in relation to the industries of the country and are anxious to co-operate in and support it.

What seems to be immediately urgent is to have some method of co-ordination and direction which shall combine the efforts of all, along the lines for which each is best adapted and which would tend to avoid duplication and promote efficiency of action. To this end the Minister has been more or less in continuous communication and conference with representatives of the Universities, the Canadian Manufacturers' Association and the scientific institutions The consideration thus given has resulted in a practical unanimous agreement both as to the necessity of immediate action and as to the lines along which it should be taken.

The Minister, therefore, recommends the appointment of a Committee of Council to consist of the Minister of Trade and Commerce, the Minister of the Interior, the Minister of Mines, the Minister of Inland Revenue, the Minister of Labour, and the Minister of Agriculture, which shall be charged with, and responsible for, the expenditure of any moneys provided by Parliament for scientific and industrial research, and also an Honorary Advisory Committee, responsible to the Committee of Council, to be composed of nine members, representative of the scientific and industrial interests of Canada, who shall be charged with the following duties —

(*a*) To consult with all responsible bodies and persons carrying on scientific and industrial research work in Canada with a view to bringing about united effort and mutual co-operation in solving the various problems of scientific and industrial research which from time to time present themselves:

(*b*) To co-ordinate as far as possible the work so carried on so as to avoid overlapping of effort, and to direct the various problems requiring solution into the hands of those whose equipment and ability are best adapted thereto:

(*c*) To select the most practical and pressing problems indicated by industrial necessities and present them when approved by the Committee to the research bodies for earliest possible solution.

(*d*) To report from time to time the progress and results of their work to the Minister of Trade and Commerce as Chairman of the Committee of Council.

That a competent Secretary be appointed on the nomination of the Committee and paid by the Department of Trade and Commerce.

That the travelling expenses of the Committee shall be paid by the Department of Trade and Commerce.

The Committee concur in the foregoing and submit the same for approval.

RODOLPH BOURDEAU,
Clerk of the Privy Council.

APPENDIX V.

MEMORANDUM ON THE SUGGESTIONS MADE BY THE GOVERNMENTS OF VICTORIA AND NEW SOUTH WALES FOR MAKING THE SCHEME FOR THE ORGANISATION AND DEVELOPMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH APPLICABLE TO THE WHOLE EMPIRE.

1. The Committee of the Privy Council for Scientific and Industrial Research have considered the papers communicated to them by the Secretary of State for the Colonies on the 23rd November 1915 and the 3rd January 1916, including memoranda by the Minister of Public Works of Victoria, and by the Honourable Premier for New South Wales. It is suggested in these memoranda that the scheme described in the White Paper issued by Mr. Arthur Henderson on the 23rd July 1915 [Cd. 8005], and subsequently embodied in the order in Council of the 28th July 1915 (which is reprinted as an appendix to this memorandum), should be extended and made applicable to the Overseas Dominions, or even to the Empire as a whole.

2. In the memorandum by the Minister of Public Works of Victoria, special stress is laid on the statement made in paragraph 3 of the White Paper that—

> "it is clearly desirable that the scheme should operate over the Kingdom as a whole with as little regard as possible to the Tweed and the Irish Channel. The research done should be for the Kingdom was a whole, and there should be complete liberty to utilise the most effective institutions and investigators as available, irrespective of their location in England, Wales, Scotland, or Ireland."

The Committee of the Council have no hesitation in expressing their concurrence in the view that the principle of the passage above cited is capable of a much wider application, and so far as in them lies, they are prepared to co-operate cordially with the Secretary of State in promoting such an arrangement between the Mother Country and the Overseas Dominions as would secure the effective application of the principle throughout the Empire. A complete and effective system of research implies the power to carry out each piece of work in the place where the conditions are most favourable and where it can be performed most thoroughly, quickly, and economically. It is obvious that a reciprocal arrangement by which the scientific and industrial resources of the Mother Country in men, material, and equipment could be made available for a research in which any of the Dominions was primarily interested, and which conversely would place the resources of the Overseas Dominions at the disposal of the Mother Country and of each other, would greatly augment the aggregate research capacity of the Empire and enhance the productivity of its industries.

3. The simplest form of Imperial co-operation would be an arrangement by which one Government (or some administrative body acting under its authority) would act as the agent of another Goverment for the purpose of arranging, carrying out, and supervising a specific research, the entire cost being borne by the Government initiating the research. It is not outside the existing powers of the Committee of the Privy Council to aid a research intended to benefit a British industry, even though the research may be conducted beyond the borders of the United Kingdom. For instance, the best means of recovering a metal found in one of the Overseas Dominions and needed for the production of some new alloy required by the British Metallurgical or Engineering Industry, might form the subject of a research conducted in that Dominion at the instance and at the cost of the Committee of Council. For this purpose their Advisory

Council would naturally try to find some body or institution in the Dominion willing, as the Committee's agent, to arrange for and supervise the actual execution of the research. Conversely, there is no reason why the Committee of Council or their Advisory Council should not act as the agent for an Overseas Government (or for any body or institution acting under the authority of the Government), for the purpose of arranging and carrying out on its behalf and at its cost any research which could more conveniently or effectively be conducted in the Mother Country. For instance, it may be worth while for an Overseas Dominion to defray the cost of a research in the Mother Country into the best method of utilising an earth or metal which is found in the Dominion but for which there is not at present a sufficient market in the Mother Country, with a view to creating such a market.

4. If, however, an effective agency arrangement were established between different parts of the Empire, it is highly probable that this relation would quickly develop into a more intimate and a more highly organised relation. The scope and methods of modern scientific research, especially when it is directed to the solution of the practical problems of trade and industry, are such as often to require the combined efforts of many workers in many places, involving a co-ordinated division of labour, and a series of investigations into problems arising at many points in the process between the raw material and the finished product. When the raw material is produced, and especially where it is grown, in one part of the world and manufactured in another, a satisfactory solution of the series of problems with which the industry is confronted will often require concurrent and concerted investigation in both countries. For instance, wheat, cotton, silk, rubber, and wool offer a number of distinct though related problems which intimately affect more than one of the constituent parts of the Empire, and which can be most effectively dealt with by simultaneous and co-ordinated investigation in different parts of the world. In such cases, moreover, it is not at all likely that the commercial interests of the two countries in the results of the different parts of the research will be so distinct as to admit of separate valuation of and separate payment for the work actually done for each country. The character of modern organised research, and the character of modern commerce and industry, are in fact such as to render it almost inevitable that a relation which starts as one of reciprocal agency between different parts of the Empire should lead to a more definitely co-operative relation of "joint venture" or "limited partnership." Under such an arrangement two or more parts of the Empire would combine to frame a scheme for the investigation of a specific problem in which they were all jointly interested, would contribute in agreed proportion to the cost of the whole work, and would arrange between themselves for the distribution of the work among the laboratories, factories, &c., at the disposal of the contributories for the supervision of the work and for the collection, statement, and use of the results achieved.

5. It is not inconceivable that in the future the relations of agency or "joint venture" may lead to a still more extensive and comprehensive partnership or union of interests. The White Paper already referred to declares, at the end of paragraph 3, with reference to the United Kingdom, that "there must be a single fund for the assistance of research under a single responsible body." The question whether it would be practicable to extend this principle to the whole Empire by the constitution of a Central Body for the purpose of administering a common fund supported by contributions from the United Kingdom and Overseas Dominions, raises issues with which the Committee of Council are not competent to deal. The "pooling" or consolidation of the resources of the Empire for the purposes of scientific research is a stimulating ideal, but though pure science is cosmopolitan and disinterested, it is in its application to trade and industry inevitably

effected by the divergent commercial interests of individuals and Governments, and the wide separation in space and the great diversity of the components of the British Empire, are still material considerations of which full account must be taken in thinking of any scheme for unified administration.

6. The Committee of Council, however, believe that even at the present time, when the energies of the Empire are so pre-occupied by the war, it is not only possible but very desirable to make an advance in the direction suggested by the Governments of Victoria and New South Wales.

It may not be possible during the war to undertake, either at home or in the Overseas Dominions, any researches involving the concerted work of a large number of trained researchers, or the provision of extensive plant and equipment. On the other hand, the Committee of Council are more than ever convinced that during the war it is essential to prepare and test, if only on a relatively small scale, an organisation by which the scientific resources of the Empire can be mobilised on a large scale immediately the war is over. The success of anything like an Imperial Scheme of Research must ultimately depend at least as much upon the skill, foresight, and care with which it is managed as upon the zeal and goodwill of the Governments, universities, and industries which co-operate in it; and it would be very imprudent to wait until the demand has become heavy and urgent in the hope of then improvising a satisfactory system of management.

7. The Committee, therefore, suggest that if the general proposal commends itself, each Overseas Government which is willing to enter into a co-operative arrangement should, as a first step and at an early date, constitute some body or agency having functions analogous to those of the Advisory Council which acts for the United Kingdom.

The Committee of Council have, of course, no intention of suggesting that the particular arrangement adopted for the United Kingdom should be taken as a model by other parts of the Empire. The Committee of Council as originally constituted consists of six Ministers *ex-officio* and three ex-Ministers. This body is ultimately responsible for asking Parliament to furnish the necessary funds and for approving their expenditure. It is an essential part of the scheme that all proposals for research shall stand referred to an Advisory Council which is a relatively small body, mainly consisting of eminent scientific men and men actually engaged in industries dependent upon scientific research, and that this Council shall take full responsibility for the scientific and technical soundness of all research proposals recommended by them for State assistance.

In the case of the Overseas Dominions the precise relation of any new body or agency to the Central or the State or Provincial Government, or to a particular Ministry, must obviously depend on local conditions and local preferences. It is, of course, assumed that it would be supported by the resources and influence of the Ministry of Commerce, as in the United Kingdom the resources and influence of the Board of Trade are available for working the scheme of research in its commercial and industrial relations.

The Committee of Council, however, venture to lay stress upon two points. First, any bodies or agencies instituted for the purpose should, under their respective Governments, have really responsible functions and substantial authority. The several bodies, moreover, should be at liberty to communicate freely with one another, and should within the limits of the funds placed at their disposal, be empowered to negotiate with one another for the formation and execution of schemes of research. Secondly, a close connection should be maintained between these bodies and the public educational systems and institutions of their respective countries It is obvious that the work of Universities and other institutions for advanced scientific and technological education will both affect and be affected by a State system of research, and that the systematic

development of research must ultimately depend upon an adequate supply of men and women who are fitted by their training to undertake it. So far as the extended scheme or research involves consideration of the educational problems of different parts of the Empire, it would possibly form an appropriate subject for consideration at the next Imperial Educational Conference and the next Conference of the Universities of the Empire

8. It is too soon for the Committee of Council to speak as to the working of the scheme which has been established in the United Kingdom. One of the most important functions of the Advisory Council is to promote a better understanding and a closer union between men engaged in science and in industry. Considerable use has already been made by the Advisory Council of sub-committees reinforced by suitable experts in particular branches of science or industry, such as were contemplated by paragraph 8 of the White Paper, and arrangements are now being made to give effect to the principle of paragraph 7 of the White Paper by setting up certain representative Standing Committees for the great scientific industries of Engineering, Metallurgy and Mining.

9. The Committee of Council would gladly co-operate with the Secretary of State in establishing and conducting any central organisation which it may be found desirable to set up in London for the purpose of facilitating and carrying on the business of an Imperial Scheme of Research. Some kind of central office, information bureau, or clearing house would be required, and, to start with, it might be possible to use, and, as occasion requires, to extend for this purpose the staff of the Advisory Council. A beginning has already been made by the Advisory Council in the compilation of a Register of Research, the scientific and industrial utility of which would be obviously greatly increased if its scope were extended to all parts of the Empire.

10. No reference has been made in this memorandum to the research work which is already done on behalf of the Overseas and Exchequer-aided Colonies and Protectorates by such institutions as the National Physical Laboratory and the Imperial College of Science and Technology, as well as by the laboratory of the Imperial Institute. Close relations between the Advisory Council and these institutions are being established, and it is, of course, assumed that in any extension of the Research Scheme to the Overseas Dominions full use would be made of the facilities offered by these and similar institutions, and of the experience possessed by the bodies and persons concerned in carrying on their work.

FOMES OFFICINALIS (Vill.), A TIMBER-DESTROYING FUNGUS.

J. H. FAULL.

This fungus was among the first to be recognized by the ancients, who discovered that it possessed pronounced medicinal properties—for centuries reputed to be of great virtue in the treatment of practically all the ills to which mankind is subject. Down to the time of Linnaeus it passed under the name of *agaricum*. With the adoption of the Linnaean system it received the name of *Boletus Laricis* from Jacquin (Jacquin, N.J.: Miscellanea austriaca ad botanicum, etc., 1778), *Boletus officinalis* from Villars (Villars, D.: Histoire des plantes de Dauphiné, etc., 1789), and *Boletus purgans* from Persoon (Persoon, C. H.: Synopsis methodica fungorum, etc., 1801). Fries published it under the combination *Polyporus officinalis*, by which name it has continued to be best known ever since. Murrill[18] rightly transferred it to Gillet's[8] new genus, Fomes, founded to include the perennial polypores, but his choice of the earliest specific name, *Laricis*, does not conform to the decision of the Brussels International Botanical Congress (1910) to make Fries' Systema mycologicum (1821) the starting point of our mycological nomenclature.

Certain French botanists have considered that a very close relation exists between *Fomes officinalis* and *Polyporus sulphureus*; and so Quélet[21] makes it a variety of *Polyporus sulphureus*, and Costantin et Dufour[5] state that "cette espèce n'est peut-être qu'une variété du *P. sulphureus*, pourrant sur le Mélèze". It is true there are distant resemblances in texture, and a close similarity in the kind of decay produced by them, but they are strikingly unlike in form, structure, taste, content, and longevity; and these features together with my cultures of both show that they are unquestionably specifically distinct.

Through the courtesy of Dr. H. D. House I have had an opportunity of making a critical examination of Professor Peck's type of *Polyporus albogriseus*, and have no hesitation in accepting Murrill's interpretation of it as *F. officinalis*. In appearance, taste, texture and structure there is no distinction between the two.

DISTRIBUTION AND HOSTS.

Records from the time of Dioscorides and Pliny onward show that in the old world *Fomes officinalis* is known to occur on the larch only—on *Larix europaea* and *L. sibirica*; and its distribution is practically that of its hosts. It is found in the mountains of middle and southern Europe, in northern Russia, Siberia, and Asia Minor according to Harz,[11] and is especially abundant and frequently of large size in the neighbourhood of Archangel, coming on the market in sizes varying from "$\frac{1}{4}$ to 10 und 15 Pfund" weight.

The first record in America appears to have been made by Calkins[3] in 1886, who found it on living white pine in Michigan. He and others are said to have used it in place of quinine. Macoun collected it on spruce in British Columbia (1889), MacDougal collected it on the same host in Montana (1901), and Longyear on *Larix laricina* and *Pinus strobus* in Michigan. Since then, it has been reported from Nevada, Oregon, Washington, California, Montana, Idaho, Arizona, Wisconsin and Wyoming. Hedgcock[12] states that it is known to attack *Abies concolor*, *Larix occidentalis*, *Picea Engelmanni*, *P. sitchensis*, *Pinus lambertiana*, *P. murrayana*, *P. ponderosa*, *Pseudotsuga taxifolia*, and *Tsuga heterophylla*. He adds that "in northern Arizona, *Pinus ponderosa* is diseased more often with this than any other fungus". To the list given Graves[9] adds *Abies magnifica* in California, Weir[26] reports *F. officinalis* on living *Pinus monticola*, *Abies grandis*, and *Tsuga mertensiana* in Idaho, and Meinecke cites *Pinus Jeffreyi*. Meinecke,[16] in his neat little Manual for Field Use, "Forest Tree Diseases Common in California and Nevada", affirms that "the chalky quinine fungus (*Fomes laricis*) forms, together with *Trametes pini* and *Armillaria mellea*, the only serious menace to sugar pine, on which it is most often found. It may, however, attack Jeffrey, yellow, and lodgepole pine, Douglas fir, and other conifers. . . . The fruiting bodies often grow on large open wounds, forming large irregular, perpendicular rows. Two or more fruiting bodies may appear on the same tree at different heights. Altogether the fruiting bodies are not common". Neuman[19] extends the list to *Larix laricina* in Wisconsin. He says that the fungus has been reported by various collectors as found on larch in the northern part of the state and a doubtful specimen is reported by Dodge from Algoma, Ontario. He reproduces a photograph of a gigantic specimen preserved in the museum of the University of Wisconsin, which measures 65 cm. in height and 105 cm. in circumference at its thickest part, and which shows about 70 strata.

Though not recorded by American botanists before 1886, *Fomes officinalis* had been collected in America much earlier than this. Dr. D. Lyall made collections as early as 1860, probably all from British Columbia. Two specimens collected by him are preserved in Kew Gardens and listed in the Official Guide to the Museum of Economic Botany No. 2, 1895. Through the courtesy of the Director of the Royal Botanic Gardens, Kew, I have received fragments of both, and the following information: "In the case in question in Museum No. 2, there are two specimens of *Fomes officinalis* from British North America, both collected by Dr. D. Lyall. Fragments of these specimens are enclosed, numbered (1) and (2), and the following details may be added. (1) Abnormal specimen, and appears to have been covered at some time with varnish. Only the Kew label is attached, bearing the data—'British North America, Dr. Lyall, 1862', together with the information as to its use by the Indians which is quoted in the Museum Guide. There is the further note on the label that about one tablespoonful of the powder is used as a dose.

"I have been unable to find out whether this information was furnished by Dr. Lyall. On looking up the records I have found only two lists from Dr. Lyall where fungi are mentioned, one dated 1859 and the other 1860. Both are lists of specimens sent from the British North American Boundary Commission, and in each case the item is given generally as a 'collection of fungi, lichens, etc.', with no details. A list was evidently sent with the 1859 consignment, but it has not been possible to find this.

"(2) A better developed specimen, growing on burnt wood. The Kew label gives the information—'British North America, East Kootenay River, Dr. Lyall, 1862'. On the back of the specimen, however, there is a pencil note with the locality and date 1861.

"The dates on the specimens are later than those of either of the Boundary Commission lists mentioned above, but it is possible that the Kew dates are merely those of the year when the specimens were deposited in the Museum.

"No information is available as to the host plant".

My own acquaintance with this fungus began in 1905 on finding a single fruiting body on a white pine log in the outskirts of Toronto, Ontario. I have since made further collections from the same general locality and have discovered that it occurs widely throughout the province—always on the same host, *Pinus strobus*. Mr. J. W. Bartlett, Superintendent of Algonquin Park, who has been intimately acquainted with the white pine areas of Canada for nearly half a century, informs me that it was well known to many of the early settlers and gathered

by them for various uses. Mr. Bartlett writes: "I have always known them as the **Pineapple fungus*. In the early days settlers used them instead of hops for making yeast; they were also added to a brew of home-made beer. They are very bitter and used to be considered a good tonic". "They are fairly common all over Ontario and Quebec, that is to say I have found them in many sections while lumbering. They were a highly valued substitute for hops in the making of yeast. Going back sixty years, my wife's mother, one of the early settlers in the township of McNab, used them for years in bread making. A piece of the pineapple fungus was boiled, as is done with hops, and the liquid put into the new yeast to start it working. I have known it ever since I came to Canada, but cannot say where the early settlers got their information regarding it. They also used Maple Rag, the lichen found growing on the maple tree, and also the seeds of the Ironwood.† The two latter I have frequently used myself to make bread". The fruiting bodies commonly occur on the "green" pine, that is, on living trees, but are also found on dead wood. A specimen in Mr. Bartlett's possession, collected in Algonquin Park, measures 1 foot in height by 7½ inches by 7½ inches, weighs (dry weight) about 5 pounds, and shows 15 years of growth. (Fig. 3).

It is uncertain whether or not the settlers brought their knowledge of this fungus with them, discovered it independently, or learned of it from the Indians. The only information on this point I have been able to secure is the statement on a label of a specimen in the Museum of Economic Botany, Kew Gardens, collected by Dr. D. Lyall about 1860—"from British North America, where it is used by the Indians as a purgative".

---

*Pineapple originally, that is in Anglo-Saxon, Middle English and later, meant pine cone.

"His (the pine's) fruite is great Boulleans or bawles of a brown chestnut colour, and are called *pine-apples*." Lyte in Dodoens.

And similarly pine trees were called pineapple trees.

"Now for *pynappul tree*
The colde or weetische land must sowen be."
—Palladius Husbondrie, p. 98.

Gerard in his Herbal included all coniferous trees under this name. "Wherein he (Pliny) was somewhat deceived, and especially in that he took Glandifera for Conifera, that is those trees which bear mast or acornes for the *Pineapple* trees".

Now obsolete, it is interesting that this old word is still perpetuated in its original sense in connection with *Fomes officinalis*. It is also interesting that the name pineapple was borrowed and applied to the fruit of *Ananas ananas* at the time of its introduction because of its resemblance to a pine cone, and that the name has been so wholly monopolized by the borrower.

†Ostrya virginiana.

The finest specimen I have seen came to me through the interest and courtesy of Mr. J. H. White—a specimen two feet long (vertical axis), and showing 45 annual layers. (Fig. 1). It was collected by Mr. D. R. Cameron, a graduate in Forestry from the University of Toronto, on *Pinus monticola*—a host not then recorded—at Revelstoke, B.C., 1911, in the Columbia Valley, growing suspended from the inclined trunk of a living tree. Dr. C. D. Howe also made a collection in British Columbia on Douglas fir, in the summer of 1912.

HISTORICAL.

Fomes officinalis was the Agaricum of the ancients, an appellation for this fungus that still survives in the folk-lore of the province of Dauphiné in eastern France. Buller[2] reminds us that the origin of this name is made clear from the statement of Dioscorides in his Materia Medica, that it was imported into Greece and Italy from Agaria of Sarmatia, a district in the south of Russia, the home of the Agari, a people who were held to be skilled in medicine. Harz[11] recounts that for centuries Greece and Italy obtained their supplies of the "larch-fungus" from the city of Agaria and neighbourhood in Sarmatia. In more modern times Archangel in northern Russia has been the main collecting and distributing centre for this drug.

The ancients, as recorded by Dioscorides, recognized two kinds[2]—"One kind is male, the other female, which differs from the male in having straight fibres within: the male is roundish in form and of the same texture throughout; in taste both kinds are similar, at first sweet, then, after being in the mouth a little time, bitter". Buller[2], who has recently reviewed in a very interesting fashion the mycological lore of the classics, explains Dioscorides' misconception regarding the sexuality of *F. officinalis* in this way. "Commercial Agaricum, according to Paulet, used to consist of fruit-bodies with the upper scaly crust and the lower layer of hymenial tubes removed. It seems likely, therefore, that the *male* Agaricum of Dioscorides was simply the fruit-body of *Polyporus officinalis* in the commercial state, and that the two forms of Agaricum were called male and female simply as a means of distinguishing them". But Pliny's view of the sexual differences, it may be observed, was based on other grounds, in part on differences in taste—a difference, in accord with my own observations, that actually exists—for in his Natural History we find the following definition[2]: "The Agaricum grows like a fungus on trees around the Bosphorus; it is of a white colour. That which grows in Gaul is considered of an inferior kind. The male is thicker and more bitter than the female; the *female*, which

is of looser texture, is at first sweet to the taste and as it is swallowed it leaves a bitter taste". Harz[11] also informs us that the "male kind" was harder, heavier, greyer, and more rimose, the "female kind" smoother on the surface, and of softer texture. These are differences that are apparently due to age and in that connection to the amount of resin present—the amount increases with age.

Dioscorides allotted to it a very important place in the materia medica of the day, affirming that[2] "its properties are styptic and heat-producing, efficacious against colic and sores, fractured limbs, and bruises from falls; the dose is two obols weight with wine and honey to those who have no fever; in fever cases with honeyed water; it is given in liver complaints, asthma, jaundice, dysentery, kidney diseases where there is difficulty in passing water, in cases of hysteria, and to those of a sallow complexion, in doses of one drachma; in cases of phthisis it is administered in raisin wine, in affections of the spleen with honey and vinegar. By persons troubled with pains in the stomach and by those who suffer from acid eructations, the root is chewed and swallowed by itself without any liquid; it stops bleeding when taken with water in three-obol doses; it is good for pains in the loins and joints; in epilepsy when taken with an equal quantity of honey and vinegar; it assists menstruation and relieves flatulence in women when taken with equal proportions of honey and vinegar. It prevents rigor if taken before the attack; in one- and two-drachma doses, it acts as a purgative when taken with honeyed water; it is an antidote in poisons in one-drachma doses with dilute wine. In three-obol doses with wine it is a relief in cases of bites and wounds caused by serpents. On the whole, it is serviceable in all internal complaints when taken according to the age and strength of the patient; some should take it with water, others with wine, and others with vinegar and honey or with water and honey".

From the time of Dioscorides to the present, Agaricum (*Polyporus officinalis*) has found a place in the pharmacopœia, though in recent times one of diminished splendour. It is still official in Austria, Germany and Switzerland, and finds a place in the French Codex, under the names Agaricus albus, Fungus Laricis, Agaricinum, Acidum agaricinum, Agaric blanc s. purgatif, Bolet du Mélèze, etc. Galen and Pliny wrote extravagantly of it, and likewise the herbalists and pharmacists down to the beginning of the last century. Turning to the most distinguished of our English herbalists[7], one finds an account scarcely less optimistic than that given by Dioscorides.

"There groweth also upon the larch tree", recounts Gerard, "a kind of mushrum or excrescence, not such as is upon other trees, but whiter, softer, more loose and spungie than any other of the mushrums,

and good for medicine, which beareth the name of Agaricus or Agaricke: I find that Pliny supposeth all the Masticke trees, and those that bear Galls, do bring forth this agaricum: Wherein he was somewhat deceived, and especially in that he tooke Glandifera for Conifera, that is, those trees which bear mast or Acornes for the Pine apple trees: but among all the trees that beare agaricus, the Larch is the chiefe, and bringeth most plenty of Agaricke. . . .

"Pliny hath said somewhat hereof, contradicting the writings of others, in his 16 booke, 8 chapter, where he saith, that specially the Acorne trees of France do beare Agaricke, and not only the acorne trees, but the cone trees also, among which, saith he, the Larch tree is the chief that bringeth forth Agaricke, and that not only in Gallia, which now is called France, but rather in Lumbardy and Piedmont in Italy, where there be whole woods of Larch trees, although they be found in some small quantitie in other countries. . . .

"The Agaricke is also called in Greek ἀγάρικον and ἀγάρικος: in Latine Agaricum and Agaricus, and so likewise in shops: The Italians, Spaniards, and other Nations do imitate the Greeke word; and in English we call it Agaricke. . . .

"Agaricke is hot in the first degree and dry in the second, according to the old writers. It cutteth, maketh thin, clenseth, taketh away obstructions or stoppings of the intrails, and purgeth also by stoole.

"Agaricke cureth the yellow jaundice proceeding out of obstructions, and is a sure remedy for cold shakings, which are caused of thicke and cold humors.

"The same being inwardly taken and outwardly applied, is good for those that are bit of venemous beasts which hurt with their cold poison.

"It provoketh urine, and bringeth down the menses: it maketh the body well coloured, driveth forth wormes, cureth agues, especially quotidians and wandering feavers, and others that are of long continuance, if it be mixed with fit things that serve for the disease: and these things it performes by drawing forth and purging away grosse, cold, flegmaticke humours, which cause the diseases.

"From a dram weight, or a dram and a halfe, to two, it is given at once in substance or in powder: the weight of it in an infusion or decoction is from two drams to five.

"But it purgeth slowly, and doth somewhat trouble the stomacke; and therefore it is appointed that Ginger should be mixed with it, or wilde carrot seed, or Lavage seed, or Sal gem, in Latine, Salfossilis.

"Galen, as Mesue reporteth, gave it with wine wherein Ginger was infused: some use to give it with Oxymel, otherwise called Syrrup of vinegar, which is the safest way of all.

"Agaricke is good against the pains and swimming in the head, or the falling Evill, being taken with syrup of vinegar.

"It is good against the shortnesse of breath, called Asthma, the inveterate cough of the lungs, the Ptysicke, Consumption, and those that spit blood: it comforteth the weake and feeble stomacke, causeth good digestion, and is good against wormes."

CHEMISTRY.

Because of the long-reputed medicinal value of the fruiting body of *Fomes officinalis*, its chemical composition and properties have been repeatedly investigated by European pharmacists, indeed, no other polypore and few other fungi have been subjected to such exhaustive pharmacologic examination. Two characters in this connection are known to every collector, namely, the odour of fresh meal that distinguishes this plant, and the extremely bitter, quinine-like taste.* So characteristic is the latter that I find the fungus named, in a recent bulletin for foresters[16], the "chalky quinine fungus".

Zellner[27], who has collated the literature on the chemistry of the fungi informs us that the following substances have been found in the sporophore of this fungus:

Water—10% (air dry)

Two hydrocarbons

A liquid fat, containing no glyceride
Fatty acids of the formulæ $C_{14}H_{24}O_2$ and $C_{18}H_{34}O_3$
A compound $C_{10}H_{16}O$ of an alcoholic nature
Cetyl alcohol
A substance of the Ergosterin group

Oxalic acid
Succinic acid
Fumaric acid
Malic acid
Tartaric acid
An organic acid of unknown nature

Trimethylamine
Glucose
Gummy substances (amorphous carbohydrates), about 6.8%
Fungin 20-30%

*In one of my collections, a young fruit-body, the taste is at first distinctly sweet, and only after some time is the bitter sensation experienced. This is probably not exceptional. The same character was noted by Dioscorides and Pliny, and Harz[25] (p. 36) also notes that the alcoholic solution of the resin is at first sweetish, then extremely bitter.

Resins:

1. Resin, red	50-70%
2. Resin, Agaricin, 18-20%	
3. Resin, white (*a*)	
4. Resin, white (*b*)	
5. A greenish yellow, soft wax	

Albumens soluble in water (0.7%) and in alkali

Ash, 0.6-1.1%

An analysis of the ash made by Smieder in material in which the ash formed 1.08% of the dry weight, yielded:

Potassium oxide (K_2O)	29.88%
Sodium oxide (Na_2O)	3.79%
Calcium oxide (CaO)	3.32%
Ferrous oxide (Fe_2O_3)	2.41%
Magnesium oxide (MgO)	16.15%
Sulphur trioxide (SO_3)	2.10%
Silicon dioxide (SiO_2)	2.33%
Phosphoric pentoxide (P_2O_5)	16.11%
Chlorine	4.33%
Carbon dioxide	18.22%

In this same material Schmieder found that the resin constituted 67% of the dry weight—a proportion of resin that is not equalled by any other organism. "Ein so hoher Harzgehalt steht ganz vereinzelt in der Natur da". The active principle, so far as its pharmacodynamic action is concerned, resides in these resins. Indeed, of these, agaricin is regarded as the most important, and so far is the only one that has been obtained chemically pure and thoroughly investigated. The technique employed and the properties of these various substances are given by Zellner and need not be repeated here.

Harz[11] made the interesting observation that resin formation in the fruiting body continues in all parts from year to year, resulting in the oldest strata in an enormous accumulation. As one example out of several the following analyses of a 19-year old fruiting body may be cited, the resin content being expressed as a percentage of the dry weight. It may be pointed out that these results can only be regarded as approximate; the resins obtained were not purified.

Basal portion (contains context)	68.80%
1st or oldest layer of pores	79.00%
2nd or next oldest layer	78.10%
3rd or next oldest layer	76.30%
4th and 5th next oldest layer	71.30%
6th or next oldest layer	69.70%

7th or next oldest layer	68.80%
8th or next oldest layer	59.70%
9th or next oldest layer	54.90%
10th or next oldest layer	52.00%
11th and 12th	50.60%
13th to 15th	48.00%
16th to 19th	44.90%

What part the resins play in the economy of the fungus, how they are formed and what is their source are questions of much interest and to which as yet in the main no very satisfactory answers have been given.

Zopf[28] alone appears to have expressed any view as to the use of such an extravagant production of resins and he contents himself with the explanation that they are waste products and of no further value to the plant. That they occur so abundantly in the fruit-body and to such a slight extent in the mycelium (Harz[11] could find none) indicates a striking difference in the metabolic processes of the vegetative and the reproductive parts of the plant, and would suggest that they perform some function in the latter. There is no question but that the phenomenon is specific, for though resin secretion is shared to some extent by some other fungi, more rarely, has it been reported to occur in the same way as it does in this. Resin is said to form a layer on the surface of the fruit-bodies of *Polyporus australis* Fr. and *P. lucidus*, which if true is the product of a special superficial glandular tissue; in the milk of Lactarii it occurs in drops, and again is the product of a special tissue. The colouring matters of *Pholiota spectabilis* Fr. and certain others are reputed to contain resins, and the yellowish secretions formed by all parts of *Polyporus cinnabarinus* possibly may be resinous. Harz[11] considered resin secretion as "unusual among the fungi". He examined the following Polypores and obtained not a trace of resin: "*Polyporus salicinus*, *P. igniarius*, *P. betulinus*, *P. perennis*, *P. sulfureus*, *P. squamosus*, *P. zonatus*, *P. bovinus*, *P. applanatus*, *P. hirsutus*, *P. versicolor*, *P. borealis*, *P. Schweinitzii*, *Trametes pini* and *Daedalea quercina*".

That the phenomenon as manifested by *F. officinalis*, is not unique, if infrequent, I hope to show shortly, but emphasis is to be placed on the fact that the phenomenon is specific, and that in *F. officinalis* it is developed to a much higher degree than in any other form. The value of these secretions to the fruit-body would seem to be protective. Perennial sporophores to persist from year to year must be immune from destructive agencies, and this immunity is secured in various ways, sometimes by hard crusts and tough tissues as in the *applanatus-group*, sometimes by stony tissues as in the *igniarius-group*, and in *officinalis*

and possibly others by protective secretions. The sporophores of *F. officinalis* are soft, with a very thin crust that frequently does not long persist, but this abundant secretion of resins provides against destruction by weather and by animals. An examination of many old and dead fruits has shown that in no single instance have insects or other animals assisted in their disintegration—this seems to be effected slowly and solely by the weather, and the youngest strata are the first to go. I have seen lichens on a very old dead fruit.

Support of this view is afforded by Tschirch[24] who concludes after his extensive classical researches on resins, that *they are not waste products but of definite biological purpose;* elaborated and not katabolic materials. In the same connection (24, p. 9) Tschirch also affirms the economic value of ethereal oils to their plant possessors, noting that among other uses they serve as solvent and thinning agents of resins. This calls to mind the fact that the odour characteristic of *F. officinalis* indicates the presence of an ethereal oil and suggests a reason for its production, especially in connection with the secretion of the resins.

Regarding the position of the resinous secretions on the hyphae of *F. officinalis* there is no doubt—they lie on the exterior surfaces of the threads; but concerning the way in which they are secreted and the source of the materials there is a sharp difference of opinion. Harz[11] appears to be the first to have considered these questions and he informs us that the resins are formed as little droplets just within the external surface of the hyphal walls, covered as it were by a cuticular membrane. He believes that they are formed from the wall substance, and in support of this view states that the walls continually become thinner and frequently completely disintegrate. Tschirch[23] confirms both Harz's observations and conclusions, except that he finds no evidence of the extreme reduction of the walls, maintaining that though reduced to great tenuity they are always intact. He holds that the greater part of the wall consists of a "schleim" layer which contains resinogen, that this layer is the "laboratory of resin production", and that this is the only case in which a cell wall is known with certainty to be the sole source of the resin secretions. Zellner[27] is doubtful about the wall being the source of resin, or as he phrases it "disorganization products of the fungus membrane"; this thesis he affirms is not proven.

I am convinced from my own observations that there is a frequent thinning of the hyphal membranes in the sporophore, and also that disintegration to a limited extent occurs. But I have observed that this thinning phenomenon likewise occurs in certain non-resinous polyporous sporophores and so by itself is of no weight in supporting Tschirch's dogma. On the other hand there is no support offered for

Zellner's equally dogmatic statement that resins are taken up direct by fungi from the substratum, transported to another region and there laid down in somewhat altered and characteristic form. Resins have not been shown to be food for fungi, there is no evidence relative to the destruction or removal of resins by fungi from a substratum, and on the view that they are waste products it would seem very unlikely that the vegetative hyphae of this particular fungus should have acquired the utterly useless habit of absorbing huge quantities of substances merely to be transported to the fruiting body and there dumped in their entirety.

CULTURES.

Cultures were made both from fruiting bodies and from the mycelial sheets in decayed wood from materials collected in widely separated regions, and in every case the results obtained were identical. The fungus grows readily, though slowly, on potato agar, producing a dense, though not copious, light-coloured mycelium, from which renewal was found to be impossible after a lapse of eight months. The mycelium on the medium, at first white, later becomes slightly yellowed. The threads are similar to those found in the natural substratum—they are extremely fine, not more than 2.7μ thick, free from clamp connections, and branched, the branches coming off at right angles. Chlamydospores are borne terminally and singly on the branches (Fig. 17) in great abundance. They are rather irregular in shape, as is true of such spores, varying from spherical to fusiform, the latter abruptly pointed at the apex and truncate at the base. They are even more variable in size, as the measurements of five spores taken at random show: (1) 8.16$\times$6.12μ, (2) 5.44$\times$5.44, (3) 7.58$\times$5.4, (4) 9.52$\times$5.44, (5) 10$\times$9.5; that is, they measure from 5.4-10$\mu\times$5.4-9.5μ. They are hyaline and their contents are characterized by fine granules or oil globules.

A comparison with cultures of *Polyporus sulphureus** will show at once striking differences. The mycelium of this fungus grows rather profusely on potato agar, producing a fluffy, distinctly yellowish growth. The threads of the mycelium are stout, up to 6μ, and branch frequently, the branches coming off commonly at an acute angle, and markedly finer than the trunks. There is a prolific formation of chlamydospores, in young cultures terminally, but later in any part of the hyphae (Figs. 15 and 16). They are extremely variable in size and in shape, especially in the case of the intercalary spores. The terminal spores are

*For cultures of *Polyporus sulphureus*, I am indebted to Miss J. McFarlane, M.A., Demonstrator in Botany in the University of Toronto.

ordinarily spherical to fusiform and measure from 8-16×6-10μ. The intercalary spores may be spherical or elliptical, but sometimes follow the shape of the cell from which they are formed and may be almost rectangular and up to 22μ in length by 6μ in width. The rounded spores measure up to 10μ in width. Figures 15 and 16 show clearly how distinctly different the cultures of *P. sulphureus* are from those of *F. officinalis*, so different that there can be no grounds for the classification proposed by Quélet.

The results of these cultures of *Fomes officinalis* add another polypore to the small list of those in which secondary reproduction is known to occur. Brefeld reported a sterile mycelium for 45 species cultured by him; 8 were found to produce oidia, two chlamydospores and one conidia. Tubeuf[25], Fayod[6], de Seynes[22], Ludwig[14], Patouillard have found chlamydospores in about four additional forms, including *P. sulphureus*, in which they have frequently been noted, and Lyman[15] has recently found them in cultures of one other. To these must be added a group, probably polypores, the genus Ceriomyces in which chlamydospores alone have been observed.

MYCELIUM.

This fungus is marked by a peculiarity—shared by few other wood-destroying fungi—of forming sheets or masses of mycelium in checks or cavities in the wood in which it is growing. Most of the various species of xylophilous fungi, as is well known, produce some characteristic change in the wood decayed by them. This may consist of distinctive changes in colour, or consistency, or texture, or localization of decay, or extent of decay, or in a tunnelling, or fracturing, etc. The mycelium of the majority of species is not evident, except microscopically, as it exists only in contact with the cells of the host, and in some species disappears altogether in the older parts attacked. Some species, however, do form sheets of mycelium, often of considerable extent and permanence, in cavities, frost checks, or other cracks that happen to be present; thus I have found sheets of the mycelium of *Fomes fomentarius* extending several feet in radial cracks of affected trees. *Polyporus sulphureus* and *Fomes officinalis*, however, are peculiar in that the wood affected by them fractures into more or less rectangular blocks, and that the cracks so formed are then filled in with a solid growth of mycelium. Cavities formed by other agencies are occupied in the same way, so that one sometimes finds masses of considerable volume in wood decayed by either of these species. In the case of *Fomes officinalis* I have good reason to believe that cavities may be formed through the

disintegrating action of its own mycelium, and such cavities are subsequently more or less filled with masses of mycelium. A striking example of this is illustrated in Fig. 4, a mass that came from the centre of a five-foot pine log left in an Ontario forest during lumbering operations. The entire log was badly decayed by *Fomes officinalis*, and on the middle of one end there grew a single fruiting body. Two or three years after the removal of this, another took its place; and on removing this one, I noticed that it was attached to a mycelial core, perhaps two inches in diameter. On opening up the log, it was found that the centre was occupied by a cavity, in some places 6 inches in diameter, and that this was lined with a tubular, cylindrical mycelial core—not unlike a length of white fire hose with the lower wall much thicker than the upper. This core was followed for six feet, as far as operations were carried, and was seen to continue farther. The interior of the tube was a fairy land of purest white, studded with glistening drops of clearest dew-like exudations, and the floor like the rugged bed of a mountain stream paved with closely crowded, exquisitely white mycelial boulders of many sizes and forms.

The resemblance of the mycelial sheets of *Fomes officinalis* to those of *Polyporus sulphureus* has already been pointed out, a feature that may indicate some relationship between these two forms, all the more striking as *P. sulphureus* sometimes attacks conifers. But there are differences, confirming the observations made on my cultures, that clearly establish the independence of the two species. The mycelial sheets of *Fomes officinalis* are generally more regular and abundant, they are more subject to the disintegrating effects of bacteria and weathering, and they are differently constituted. This last feature is determinative. The mycelium of *F. officinalis* consists of white, rather closely-interwoven, thick-walled threads of great fineness and uniformity, mostly 1.5μ in thickness, but sometimes up to 2μ. They are smooth, and rarely septated; there are few clamp-connections, and branches are given off at infrequent intervals and characteristically at right angles (Fig. 30). The mycelium of both species is sometimes covered, to a limited extent, with resinous secretions in the form of irregular granules, especially in the sheets. The mycelium of *P. sulphureus*, on the other hand, is marked by a lack of uniformity, for while a large proportion of the threads may be fine, down to 1.5μ in diameter, smooth, and thick-walled, these slender threads are branches of coarser hyphae, the main trunks measuring up to 6.5μ. The proportion of fine branches and coarse trunk threads is very variable. In old, thick sheets the hyphae may become encrusted. Branching, likewise, may be frequent, and is ordinarily at an acute angle.

FRUITING-BODY.

The sporophore of *Fomes officinalis* varies considerably in form, from almost globular—characteristic of the first year's growth—to ungulate or cylindrical or occasionally even fairly applanate, and it measures from 5-65 cms. in height. The maximum measurements indicate giant specimens among the fungi; Murrill[17] states that sporophores up to fifteen pounds dry weight have been found. The surface is anoderm, but soon becomes somewhat encrusted. Young fruiting-bodies, that is of one or two years' growth are chalk-white in colour or slightly yellowish, but with age there may be a mottling of yellow and white, or more commonly of gray. The change is due to a darkening of the contents of filaments in the crust, a darkening that may extend to the cell-wall and to the resinous secretions of the hyphae.

The crust in older plants is more or less radially cracked or rimose. On the lower surface, each year a new layer of pores is added, varying from 5 to 20 mm. in thickness. Extending over a period of 45 years, the specimen illustrated in Fig. 1 shows an average annual accretion of 12.5 mm. As the margin of each layer is convex, and the peripheral pores of the preceding layer are not covered by the new, the surface is strongly concentrically furrowed. The specimen recorded by Neuman[19], 65 cms. high, shows 70 strata or an annual accretion of more than 9 mm.

The context is rather tough when fresh, but firm and quite friable when dry; but these textural characters are likewise true of the porous layers, due to the fact that after sporulation, hyphae grow down so as to completely fill up the pores, to such an extent that the latter lose their identity, and very soon context and porous layers are alike in texture, and distinguishable from one another only by a poorly-defined colour zone at the boundary of each stratum. The entire surface is so friable that it is abraded in handling, a chalky-like powder adhering to the fingers. The tubes are circular to angular, 3-4 to a mm. with thin and more or less laciniate and fragile walls, white at first, later discoloured. The spores are hyaline, smooth, ellipsoid, $3\text{-}4 \times 4\text{-}5\mu$; those of *P. sulphureus* are larger, $4\text{-}5 \times 6\text{-}7\mu$.

Structurally, the sporophore has proved to be of unusual interest, in part because of the extensive secretions of resin, and in addition because of the peculiarities of the organization of the context, and because of the discovery of chlamydospores, a secondary form of reproduction not frequent in highly-organized fructifications of any kind.

The context consists mainly, except next to the pores, of unbranched, thick-walled threads about 3μ in diameter, much like those of the mycelium, though rather coarser, varying from $1.5\text{-}4\mu$, and very rarely

branched. Unbranched threads 1,000-1,500μ are readily found in any mount, while much search is required to find branching. Next to the pores, however, there are areas directly opening on the pores, and separated from one another by a matrix of the thick-walled fibres, in which the hyphae are much branched, septated, thinner-walled and rather coarser. The areolation of this region, readily seen with a hand-lens appears to be in continuity with a remarkable areolation that characterizes the organization of the entire context.

Reference to figure 5 shows that there is a very evident mottling of the context or division into areolae, and that this extends in modified form into the cortex. A microscopic examination shows that this is due, not to irregularities of resin secretion, but to the fact that the context and cortex consist of compact strands of threads bound together by a loose and irregular net of hyphae. These strands dividing into finer ones pass down towards the tubes in the one direction, while near the surface others turn upward and running almost parallel with one another form the cortex. This peculiarity of organization, shared to some extent by species of Spongipellis though not by *Polyporus sulphureus*, did not escape the notice of Harz.[11] Harz, indeed, examined this feature rather carefully, and states that if the resin be removed, it becomes plain that these strands form a common system, all originating from main trunks at the point of attachment of the sporophore to the mycelial mass in the host, these trunks dividing and redividing, ramifying and anastomosing throughout the context, and constituting a framework or skeleton of the context.

The pore-layers retain their porosity but a single season, since the pores rapidly fill with hyphae, outgrowths from the surrounding tissues. The threads of the walls are more like those of the context, while those filling the pores are much branched and septated, rather larger, and thin-walled. But throughout branching is more frequent as would be expected, and is of the various types represented in Figs. 22, 24, 25. There are likewise not infrequent abnormalities such as gall-like swellings (Figs. 19 and 20), in which it can plainly be seen that the walls of of the hyphae are laminated, and, too, there are occasional threads up to 10μ in width. The thin-walled threads are mostly from 2.5-3μ in diameter and are characterized by distinct septa and rich cell contents. (Figs. 22, 24, 25).

All the hyphae are encrusted with resin, and this resin is found secreted freely on the surfaces, continuously or at intervals. The resin granules are of two colours, white and rich golden yellow. The encrustation is extensive throughout, though more or less irregular, but it is in the outer layers, especially the crust of the sporophore that it

reaches its maximum. Here the threads run radially, closely packed, and with little branching. A common type of branching is illustrated in Fig. 22. One of the strangest features is the fact that the thin-walled, much-septated threads are by far the most abundant, and the secretion of resin is so great that a solid matrix results, in which in untreated sections of fragments they are wholly indistinguishable. Fig. 21 is a drawing of a fragment 120μ thick, from which a few thick-walled hypha are shown projecting; the mass, however, is made up of thin-walled threads arranged parallel and closely packed. By treating a section with a few drops of alcohol the resin is dissolved out and the structure becomes discernible. The resinous crust is extremely brittle, and friable.

An examination of the crust of the sporophore revealed another feature of unusual interest, namely, that here there is a formation of *chlamydospores*, especially in older parts of the fructification, and sometimes so abundantly as to constitute a fairly continuous layer (Figs. 18, *a-c*). They are formed in chains, from septated threads by a further septation, with or without enlargement, followed by a thickening of the walls. They vary in size from 2-7$\times$2-6μ, in shape from irregularly spherical to elongated, and in colour from hyaline to yellowish brown, the colour in the latter case appearing only as the spore matures; the threads from which they are successively formed in basipetal order are commonly purely hyaline. It is quite obvious that the friable nature of the sporophore, so great at the surface as to be readily worn by weathering, is an advantage in their distribution.

Two explanations now may be advanced in explanation of the occurrence of these spores, namely that they are a secondary means of reproduction, or that they are the product of another fungus, either an invader or a symbiont. That the first is the correct interpretation is borne out by a number of observations. They were found to occur in all the older fruiting-bodies which I have examined—from two localities in British Columbia, and from two in Ontario, widely separated in each case; they are found in radial chains, often in abundance, in the resinous crust, which would appear to be a barrier against invading fungi; they were found in my artificial cultures; and they are known to occur in the fruiting-bodies of certain other polypores, including *Polyporus sulphureus*, a species which shows resemblances to *F. officinalis* in other respects as already noted. The possibility of a commensal arrangement is, of course, not excluded, a theory, however, which was proven to be incorrect in the somewhat similar case of Nyctalis, for the chlamydospores on being sown produced the normal Nyctalis fructification, and cultures from the basidiospores of Nyctalis bore the same type of chlamydospores (Krombholz[13]; Brefeld[1]; Costantin[4]).

Chlamydospores have been repeatedly observed by investigators on the higher fungi. Brefeld[1], in particular, describes a considerable number, and deals with their characters and significance at length. Lyman[15] gives a fairly complete survey of the literature on this subject. He informs us that Tubeuf found them on the mycelium of *Merulius lachrymans*, that Fayod found them in the hymenium of *Polyporus lucidus*, and Farneti in the hymenium of *Boletus briosianus*. Others have reported them in species of *Polyporus* and related genera, "where they sometimes occur in such abundance as to form definite fructifications of their own—the basidio-fructification in some species is unknown or only occasionally recognizable". These chlamydosporic fructifications have been recognized under the generic name *Ceriomyces* Corda, *Ptychogaster* Corda, *Oligoporus* Bref., and perhaps *Fibrillaria* Pers. and *Lycogalopsis* Fisch. The identity of many of them is unknown, but some of them have been definitely connected with the Polyporaceae, as for example, *Polyporus biennis* Bull., *Trametes rubescens* Fr., *Polyporus sulphureus* Bull., and *Fistulina hepatica* Fr., in all of which the fructification is of the normal type and bears basidiospores as well as chlamydospores. In some of the Ceriomyces or Ptychogaster forms the chlamydospores are borne in cavities. In *Fistulina hepatica* they are borne radially just under the superficial layer of cells in the upper part of the fruiting-body—more nearly resembling *Fomes officinalis* in this respect. Lyman summarizes as follows: "Chlamydospores are known in Hemigaster, in a few agarics (especially in Nyctalis), and reach their highest development in the Polyporaceae, where they occur in many species, frequently forming definite fructifications, and nearly or quite replacing the basidiospores. It is probable also that the conidia reported by Patouillard in *Stereum disciforme*, *Corticium amorphum*, and Pterula multifida, and by several writers in species of Hydnum are chlamydospores. Aside from these doubtful cases, chlamydospores are not known to occur in the Hydnacadeae, Clavariaceae, or Thelephoraceae. In distinction from oidia, chlamydospores occur in the hymenium or other parts of the fructification, having been found on the mycelium only in rare instances". Summarizing his own work, he states that he "has found chlamydospores to be much more common, particularly upon the mycelium, than was previously known, having found them in over one-quarter of the species cultivated;* they occur in about equal numbers in the three families studied. Undoubtedly, further culture study will yield additional proof of their wide distribution among Hymenomycetes.

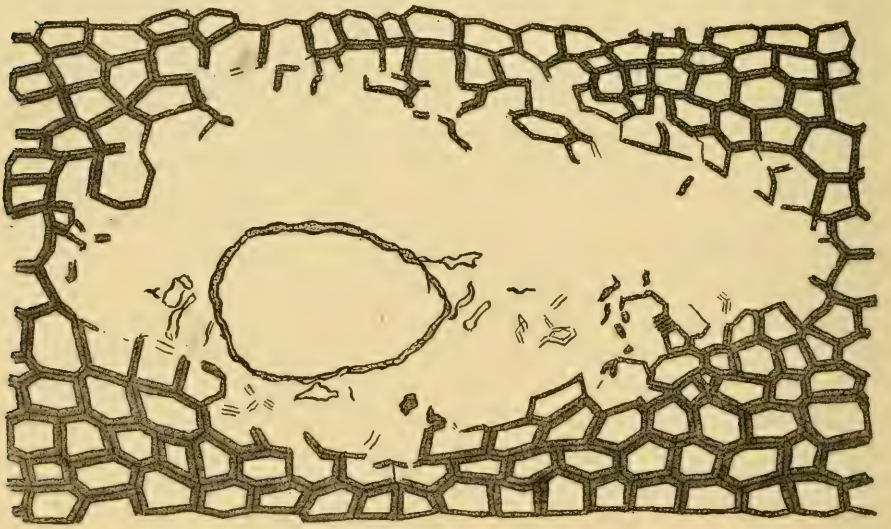
*"Seventy-five species of Polyporaceae, Hydnaceae, and Thelephoraceae (the majority belonging to the Thelephoraceae) were grown in pure cultures; about 40% were found to possess some secondary method of reproduction, usually mycelail oidia or chlamydospores."

PATHOLOGICAL.

Polyporus officinalis is the cause of a red heart rot of the stem of conifers. The affected wood darkens to a reddish brown, becomes exceedingly friable, and fractures into rectangular blocks up to an inch in diameter in some species. In the case of *Pinus strobus* the wood fractures into much smaller pieces, down to one-eighth of an inch, and cracks longitudinally both tangentially between annual rings and radially. The crevices or spaces in the fractured wood are soon occupied by sheets of mycelium, so that the diseased wood presents a very characteristic appearance—resembling that caused by but one other species, namely *Polyporus sulphureus*, differing from that form, however, by a more abundant production of softer sheets. The mycelium may wholly disappear in weathered material, or in decayed wood of long standing—the resemblance then being to the rot caused by *Polyporus Schweinitzii* or *Lenzites sepiaria* (Fig. 12). Figs. 7-10 are illustrations of decayed white pine, Fig. 11 of Douglas fir. Fig. 8 is a photograph of the radial longitudinal face of a block in the plane of a sheet of mycelium, and shows well the extent of the fracturing of the wood, and also stages (particularly at the left) of the filling in process by the fungus. These transverse smaller cracks involve most commonly but a single annual ring. Reference to Figures 9 and 10 show that there are likewise many small corresponding radial checks. An examination of sections from blocks embedded in celloidin reveals the presence of still smaller checks, sometimes affecting only a few elements (Fig. 14).

It has already been stated that the fungus seems capable of a more or less complete destruction of pine wood in localized spots in the trunk —resulting at times in the formation of mycelium-filled cavities. This is due, not to the entire digestion of the wood, but to the tendency of the wood to check indefinitely and to the vigour of the mycelium. A study of Figures 9 and 10 is convincing that such destruction may take place. Tiny fragments of wood are embedded in the thickest sheet. Fig. 6 is a photograph of the cut surface of a large mass taken from a pine trunk and represents plainly an almost solid structureless matrix of mycelium in which fragments of wood of various sizes are embedded. It is possible, and seems probable that in time the digestion may be complete, but the consumption of the residue of the walls after the cellulose has been removed is slow. In this connection Text-figure 1 is interesting, taken from a celloidin section of white pine and showing the destruction of the tissues in the neighbourhood of a resin canal. The space around the canal was occupied largely by a dense mass of mycelium, hyphae from which extended into the surrounding tracheids. Such occurrences are not infrequent in the pine I have examined.

Microscopic examination of the decayed wood shows that cellulose is removed from the walls of the structural elements, leaving the middle lamellae intact and the secondary layers represented by a gummy substance which cracks in the manner shown in Figures 13 and 14. In Figure 14 the tracheids at the extreme right have not yet been attacked and the bars of Sanio are obvious. The two lines of the X-shaped cracks where the wall has been perforated or on the bordered pits may be on opposite sides of the wall. With the removal of the cellulose there is apparently a shrinkage in volume which affects the entire mass of affected wood and which is responsible for the fracturing. The cracks in the walls of the tracheids are similar to those produced by *Polyporus Schweinitzii* and *P. sulphureus* as described by Hartig[10]—an effect that may be common in all cases where there is a removal of the cellulose only.



TEXT-FIGURE 1.

A transverse section of *Pinus Strobus* decayed by *F. officinalis*, showing a breaking down of the tissues around the resin canals.

As to the importance of *Fomes officinalis* as a destroyer of dead coniferous timber there can be no question. While preferring the heartwood, it works outward so that but a thin shell of sound wood remains, and if there be a sufficiency of moisture, the entire sapwood, as well as the heartwood, is involved. It likewise works vertically through the trunk, destroying in a tree most of the wood of merchantable value. Fallen timber and standing trunks are destroyed alike. Weakened by the decay, the trunks of standing trees often snap, the break taking

place anywhere below the crown, and not just next to the ground as in *P. Schweinitzii.*

Fomes officinalis is also a wound parasite, to be classed with such forms as *Fomes igniarius*, *P. sulphureus*, and *P. Schweinitzii.* It appears most frequently in mature trees, the fruiting bodies being commonly found on the still living hosts, and seems as certainly as in the case of other wound parasites to be the cause of their eventual death. There are no data on the amount of the losses due to this agent. In some regions it appears to be absent or infrequent, while in other parts considerable losses must have resulted (as in certain over-mature pine areas of Ontario) judging from the frequency of the *officinalis* decay in standing and fallen timber. My personal knowledge of its distribution includes the west end of the Lake Ontario region, a part of Nipissing District, and parts of Algonquin Park Forest Reserve. Mr. G. W. Bartlett, Superintendent of Algonquin Park, likewise informs me that he has seen it in many places throughout the Ottawa Valley, both in Ontario and Quebec.

As to its depredations elsewhere we know that, especially in the west, various conifers are attacked, though there are no data as to how extensively. Hedgecock[12] and Meinecke[16] report it to be the most destructive agent of the two by far most important commercial pines of Western America. They state that the principal losses to *Pinus ponderosa* in northern Arizona are due to *F. officinalis*, and that everywhere it is to be counted as one of the three most serious enemies of *Pinus lambertiana.* Larsen and Woodbury, in a bulletin just issued (Sugar Pine, U.S. Dept. of Agric. Bull. No. 426, December, 1916) are in agreement that "*Trametes pini* and *Fomes laricis* (officinalis) are by far the most destructive of the wood-destroying fungi which attack sugar pine".

SUMMARY.

1. Historically, *Fomes officinalis* occupied an important place in medicine, dating back to Dioscorides, and is still officially recognized in several European countries. Long before its recognition by botanists in America it was used by the early settlers in Ontario and Quebec for various purposes, including the preparation of yeast for bread making, and was known to them as the "Pineapple Fungus".* This is the first botanical record of its occurrence in those provinces. The first†

*Pineapple tree—An old English name, now obsolete, for a pine tree or a coniferous tree; *pineapple* originally meant a pine cone.

†Specimens in the Museum of the Royal Botanic Gardens, Kew, were collected by Dr. D. Lyall in British Columbia about 1860.

record in America appears to have been not earlier than 1886. There is some evidence that the Indians knew of its medicinal value.

2. The active principle is a resinous substance, Agaricin; this, with other resins, constitutes up to 70% of the dry weight of the fruiting body.

3. The resins are secreted in the form of amorphous granules to a very slight extent on the mycelium, but in great abundance on the hyphae of the sporophore.

4. Chlamydospores appear in cultures. They also occur on the sporophore, but in both cases are different from those produced by *Polyporus sulphureus.*

5. The context consists of a complicated system of strands more or less loosely bound together, and in consequence exhibits a characteristic areolated structure in sections.

6. Quélet and certain other European systematists have assumed that *Fomes officinalis* is a variety of *Polyporus sulphureus*, or specifically very close to it. They are very distinct species, however, differing in many respects: (1) Size and branching of hyphae; (2) Form, longevity and content of sporophore; (3) Structure of sporophore; (4) Size of spores; (5) Distinct differences in cultural characters.

7. *Fomes officinalis* is the cause of a red heart rot of conifers, characterized by a removal of the cellulose, by a fracturing of the wood into rectangular masses, and the formation of mycelial sheets in the crevices. Histologically, the effects are similar to those caused by *Polyporus Schweinitzii.* It occurs on living and dead timber, and belongs to the group commonly regarded as wound parasites. The losses occasioned by it in some areas are extensive. It occurs throughout Ontario and Quebec on *Pinus Strobus*, and has been reported from Michigan on the same host.

8. *Fomes officinalis* is known to occur on the following hosts:

Europe and Asia: *Larix europaea, L. sibirica.*

America: *Abies concolor, A. magnifica, A. grandis, Larix occidentalis, L. laricina, Picea Engelmanni, P. sitchensis, Pinus lambertiana, P. murrayana, P. ponderosa, P. Jeffreyi, P. strobus, P. monticola, Pseudotsuga taxifolia, Tsuga heterophylla, T. mertensiana.*

9. In America, *Fomes officinalis* is reported from:

Canada: British Columbia, Ontario, Quebec.

United States: Arizona, California, Oregon, Washington, Montana, Nevada, Idaho, Wisconsin, Michigan, Wyoming.

LITERATURE CITED.

1. Brefeld, O.: Untersuchungen aus dem Gesammtgebiet der Mykologie. Heft. 8, 1889.
2. Buller, A. H. R.: The Fungus Lore of the Greeks, and Romans. Trans. Brit. Mycol. Soc., 1914.
3. Calkins, W. W.: Polyporus officinalis, Journal of Mycology, II: 107, 1886.
4. Costantin, J.: Etude sur la culture des Basidiomycètes. Rev. gén. de bot., 3, 1891.
5. Costantin, J. et Dufour, L.: Nouvelle flore des champignons, etc. Paris, 1895.
6. Fayod, V.: Prodrome d'une histoire naturelle des Agaricarinés. Ann. des Sci. Nat., Bot. Sér. 7, Vol. 9: 181-411, 1889.
7. Gerard's Herbal (1597): Thos. Johnson's Edition, 1633, p. 1365.
8. Gillet, C. C.: Les champignons qui croissent en France, 1878.
9. Graves, A.: Fomes laricis in California. Phytopathology, IV: 33, 1914.
10. Hartig, R.: Zersetzungserscheinungen des Holzes. Berlin, 1878.
11. Harz, C. O.: Beitrag zur Kenntniss des *Polyporus officinalis* Fr. Bull. Soc. imp. des Nat. de Moscow, Vol. 41: 1-40, 1868.
12. Hedgcock, G. G.: Notes on Some Diseases of Trees in Our National Forests II. Phytopathology, II, 1912.
13. Krombholz, J. V.: Essbaren Schwäme I, 1831.
14. Ludwig: Ptychogaster albus Corda. Die Conidien-Generation von Polyporus Ptychogaster, n.sp. Zeit. f. Naturwis, Vol. 53: 424, 1880.
15. Lyman, G. R.: Cultural Studies on Polymorphism of Hymenomycetes, Proc. Bos. Soc. Nat. His. 33: 125-210, 1907.
16. Meinecke, E. P.: Forest Tree Diseases Common in California and Nevada. U.S. Dept. of Agric., 1914.
17. Murrill, W. A.: The Genus Fomes. Bull. Torr. Bot. Club, 1903.
18. Murrill, W. A.: North American Flora, Vol. IX, 1908.
19. Neuman, J. J.: The Polyporaceae of Wisconsin. Wis. Geol. & Nat. His. Survey, Bull. 33.
20. Patouillard, N.: Observations sur quelques Hymenomycètes. Rev. Mycol. 3: 10-12.
21. Quélet, L.: Flore mycologique de la France, etc., 1888.
22. de Seynes, J.: Les conidies de Polyporus sulphureus Bull., et leur développement. Compt. rend. Acad. Sci. Paris, Vol. 86: 805-808, 1878.
23. Tschirch, A.: Die Harze und die Harzbehälter, Vol. 2, Leipzig, 1906.

24. Tschirch, A.: Die Chemie und Biologie der pflanzlichen Sekrete. Leipzig, 1908.
25. Tubeuf, C. von: Beitrag zur Kenntniss des Hausschwammes, Merulius lacrymans. Centralbl. f. Bakt., Paras., und Infekt. Pt. 2, Vol. 9: 127-135, 1902.
26. Weir, J. R.: New Hosts for some Forest Tree Fungi. Phytopathology, V: 71, 1915.
27. Zellner, J.: Chemie der höheren Pilze. Leipzig, 1907.
28. Zopf, W.: Die Pilze, 1890.

DESCRIPTION OF PLATES.

Fig. 1. A 45-year old fruit of *Fomes officinalis* nearly 60 centimetres high, collected from a living *Pinus monticola* by Mr. D. R. Cameron.

Fig. 2. A one-year old fruit, 5 cms. wide, from *Pinus Strobus*.

Fig. 3. A 15-year old fruit, 30 cms. high, collected from a living *Pinus Strobus* by Mr. G. W. Bartlett.

Fig. 4. A tube of mycelium, slitted along one side and opened up, 40 cms. long, collected from a hollow in the axis of a log of *Pinus Strobus*.

Fig. 5. A longitudinal section of an 8-year old fruit, 14.4 cms. high, collected from *Pinus Strobus*. This shows a characteristic areolation of the context.

Fig. 6. Section through a matrix of mycelium in which fragments of decayed wood are embedded. Taken from a log of *Pinus Strobus* in which it was in continuation with the mycelium shown in Fig. 5. Horizontal diameter is 9 cms.

Fig. 7. Typical decay of *Pinus Strobus* caused by *F. officinalis*. Specimen is 24 cms. long.

Fig. 8. Part of a specimen similar to the one used in Fig. 7, smoothed and photographed. About 2.5 x.

Fig. 9. Transverse view of a specimen similar to the one used in Fig. 8.

Fig. 10. A part of the specimen used in Fig. 9. About 2.5 x.

Fig. 11. Typical decay of *Pseudotsuga mucronata* caused by *F. officinalis*. Specimen is 13 cms. high.

Fig. 12. A piece of white pine decayed by *F. officinalis* and then weathered. Length 32 cms.

Fig. 13. Transverse section of *Pinus Strobus* decayed by *F. officinalis*.

Fig. 14. A longitudinal section of the same as Fig. 13.

Fig. 15. A portion of the fruiting mycelium of *Polyporus sulphureus* from a culture.

Fig. 16. Chlamydospores from the same culture as in Fig. 15. Various sizes and shapes are shown in the series *a*, *b*, *c*, *d*, *e*.

Fig. 17. A portion of the fruiting mycelium of *Fomes officinalis* taken from a culture.

Fig. 18. Chlamydospores from the crust of a fruiting body of *F. officinalis*.

Figs. 19 & 20. Abnormal hyphae from the context of a fruiting body of *F. officinalis*.

Fig. 21. A fragment from the fruiting body of Fig. 5. This piece consists of a solid matrix of translucent yellow resin in which are embedded thin-walled hyphae, like those of Figs. 22 and 23, and a smaller number of thick-walled threads.

Figs. 22-25. Types of hyphae from the fruiting body of *F. officinalis*. Fig. 22 shows a type common near the surface, the branches passing out parallel. Fig. 24 shows a small amount of resinous secretion in the form of granules.

Figs. 26-29. Hyphae from the fruiting body of *F. officinalis* showing secretions of resin in varying amounts.

Fig. 30. Hyphae from mycelial sheets of *F. officinalis* taken from white pine, with and without resin granules, and in *a* showing the character of the branching.

1

2

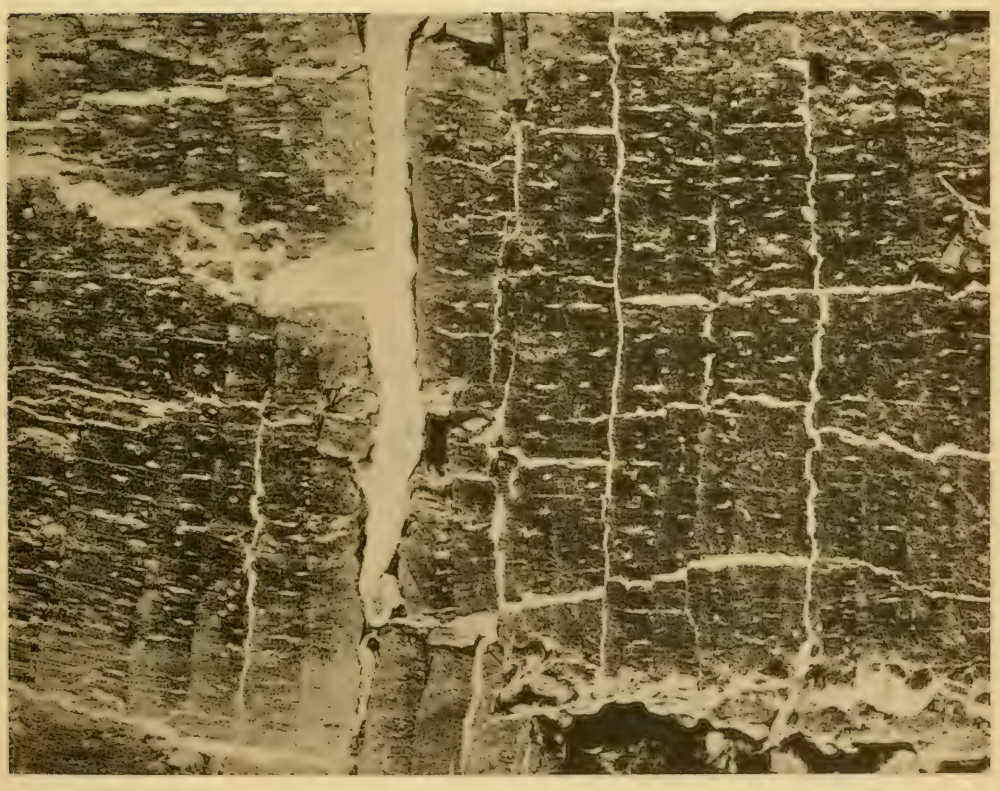
3

4

5

6

7



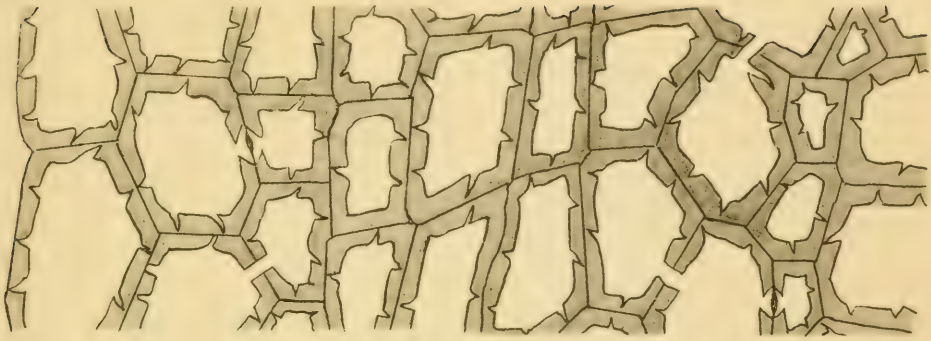
8

9

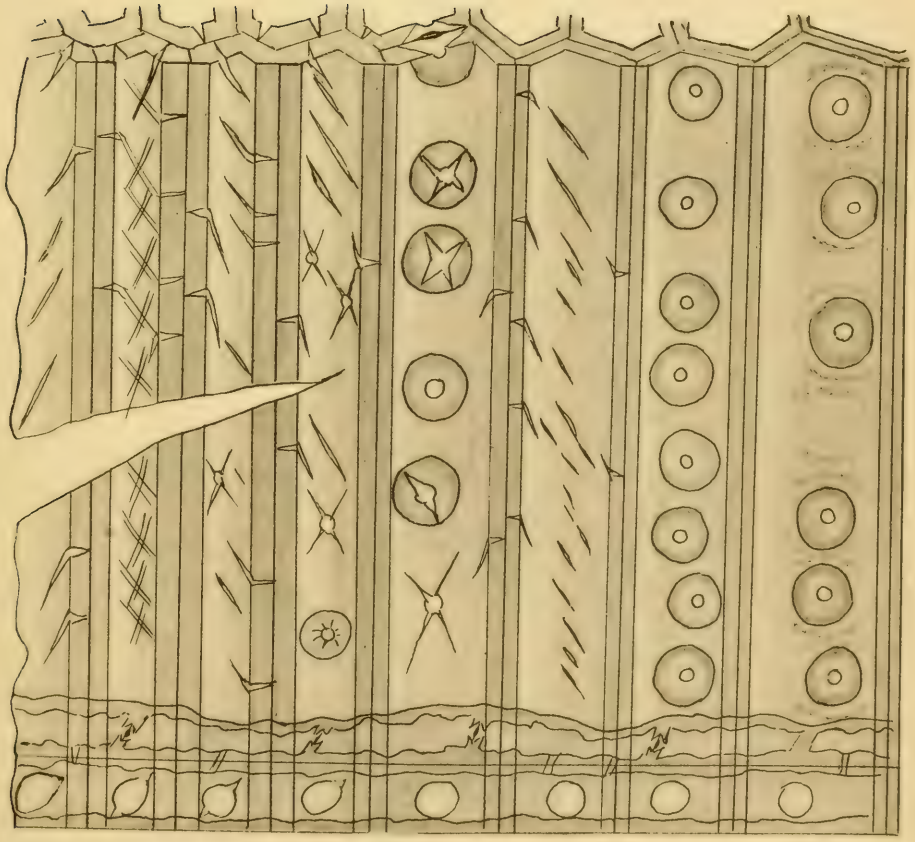
10

11

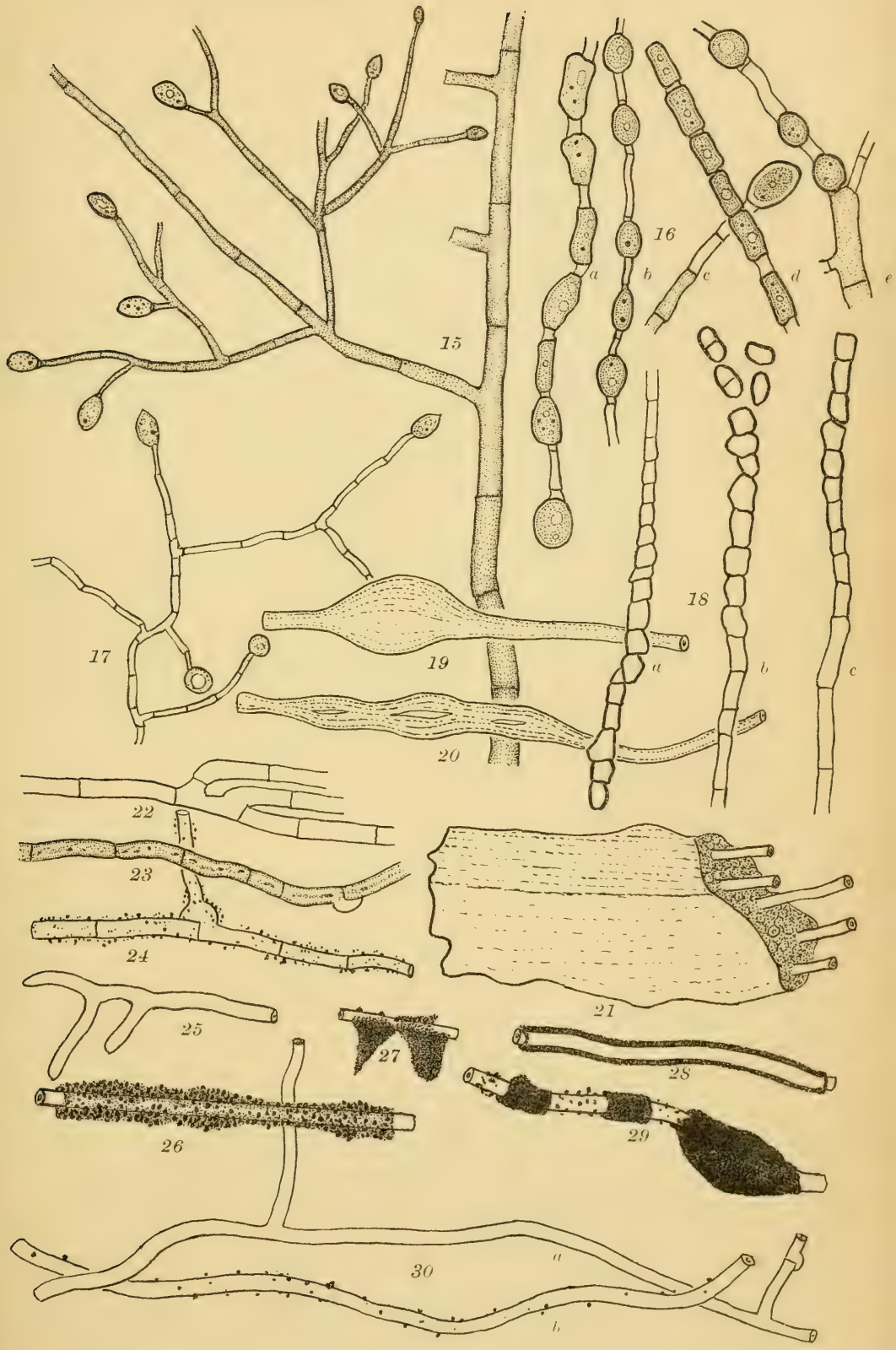
12



13



14


15
16
a
b
c
d
e
17
18
a
b
c
19
20
21
22
23
24
25
26
27
28
29
30
a
b

AGRICULTURE IN WAR-TIME.

By Frank T. Shutt, M.A., D.Sc.
Dominion Chemist.

Education.

The war has many lessons for those who will learn them, sad lessons many of them certainly, but valuable lessons for the most part for the peoples and the nations involved in this great conflict in which we of the British Empire with our Allies are battling for righteousness, justice and honour. Our view point on many matters has been shifted, but what is perhaps of greater importance I think we have a clearer and better estimate of the things that in the long run really matter in this life, a truer conception and more intense realization of the inherent rightness and wrongness in those qualities and characteristics which determine our attitude and actions towards one another, whether as individuals or as nations.

It is not, however, our purpose to consider these matters, important as they are to us as a people, but what I have said may serve as an introduction, or indeed explanation of the statement that the estimate and conception of the people at large as regards agriculture has greatly changed in these later, let us hope, latter days of the war. We have I think awakened or at least are awakening to the realization that the food supply, which means agriculture, is playing a vitally important part, not merely in the welfare, but the very existence, of the nations at war. The food supply may be the factor that will turn the scale in the final winning out of the war, certainly it is only second in importance to the supply of ammunition and the successful prosecution of arms on the field of battle. We at least know that it is mainly the shortage of food in Germany that prompted the recent overtures for peace from that country.

And this matter of the importance of agriculture as an industry affecting the welfare of a country has touched us nearer home. In the recent advances in the price of our food stuffs, more especially pronounced since the outbreak of the war, we of the towns and cities—consumers and not producers—are learning the stern lesson of how dependent we are on the output of agriculture. Until a few years ago, living in this land of plenty and of cheap food, we never gave a thought as to how this food was produced or where it came from. The inter-

dependence of town and country was not a subject that entered into our consideration. It is not our purpose to-night to discuss the causes which have led to the present high cost of living, but I may say in passing that the blame, if blame there is, does not altogether lie with the farmer, as many suppose. He suffers with us in the high prices that prevail. All the things that he does not actually produce and which he must buy, even his concentrated cattle foods—the products of milling, etc., have gone up in price and above all the labour that he must hire to help him till his soil, put in his crops and harvest them and feed his cattle, commands to-day a wage unheard of a few years ago. The scarcity and dearness of farm labour is probably to-day the most serious problem in agriculture. If therefore the farmer to-day is getting somewhat more for his own labour and oversight and his capital invested than he did ten years ago, and I think he is, he richly deserves it; compared with other industries, agricultural labor has been but poorly paid in the past.

It has seemed to me that the question of supply and demand is very largely involved in this matter of high prices. For the facts are these, that tremendous quantities of Canadian produced food stuffs are going overseas to feed our troops and we have the distressing fact to acknowledge that our food producing population—our rural population— has decreased while our food consuming population—the population of our cities—has increased. In a word while our food consumption has increased, our food production has decreased. During the last decade there has been a steady exodus from the farm to the city—a most deplorable condition looking to the future stability and progress of our country, which is by nature undoubtedly designed to be a great food producing country.

And you may legitimately ask me why this is so? Why have the young men left the farm and sought employment in the city? Many answers have been given and the subject is worn well-nigh threadbare. Perhaps lack of love for the work has had something to do with it, for many of our farm boys have been brought up with the idea that farming is merely dirty drudgery with no outlook and no prospects. Many of our farmers, with their long experience of toil in reclaiming the forest, have encouraged rather than dissuaded their boys to remain on the farms. Anything that we can do to inculcate a love of the country, of working the soil, a love of plants and animals, will be doing our country good service. Perhaps the glamour of the city life offers opportunities for activities and amusements and mild excitement that are absent in the country. But probably the more immediate cause is the fact that the wages of the various industries and city businesses are con-

siderably higher than can be paid by the farmer. We are an ambitious people, and unfortunately that ambition has largely turned towards dollars and cents; it is not well balanced. The get-rich-quick idea affects our youth as it does that in other countries.

These are digressions, but I have purposely introduced them that you may have a clearer view of what the conditions in agriculture have been and are to-day. My hope is that we are about to enter upon a new era in our agricultural life. The war has shown us many things and with respect to agriculture it is giving us saner, sounder views. It is impressing upon us as a people the dignity and high status of agriculture as an occupation—its vital importance to the stability of the country. We are coming to realize that it is "the source and foundation of our national strength". It may not be a calling that offers great monetary returns, compared with some other occupations, but it is one that will call forth all the intelligence and mental ability that a man has, no matter how clever he may be, and give him a healthy, wholesome life with a fair recompense, provided he applies himself intelligently to its problems. There are problems in soils and crops and livestock that require knowledge and thought as well as labour to solve. I know of no occupation that provides better opportunities, more scope, for study, clear thinking and successful action. Let it not be thought that the farming of the future will consist merely of hard, physical work (though there will always be plenty of that) indeed the most successful farmer to to-day is the one working on advanced and rational lines, and who is using his head more than his hands, proving, adopting and adapting to his own conditions the findings of science and experience. It is all this that the war is bringing home directly or indirectly to the people at large. Further, the war is making very clear the value of scientific research in Agriculture. Our governments are recognizing, as they have never done before, the importance, the vital importance of scientific work if real progress is to be made towards improving farming in all its phases and branches. The British government has been most active during the past two years in enlisting the assistance of the best scientific ability in the land. This is most hopeful; our Government will follow and we may confidently expect that in the next decade great strides will be made in the science of agriculture which must react beneficially on practical farming.

Very early in the history of the war it was foreseen that there would be an extraordinary tax on the supplies of food stuffs at the command of the Empire, and that every effort must be made not only in the home land, but in all the colonies to meet it. There is no necessity I am sure to enlarge on the reasons, the conditions, that led to the urgent and

insistent call issued by the British Government for food and still more food; indeed, it is a matter of daily wonderment how the food requirements of the immense number of those engaged in actual warfare, in the making of ammunition, are met—certainly they must far exceed those that had hitherto satisfied the needs of the Old Country.

Our Federal Government and our several Provincial Governments took up the call promptly and enthusiastically in the autumn of 1914. Throughout the length and breadth of the land it went out that every farmer, if from patriotic motives only, must make an honest effort to increase his crop yields, his live stock, his dairy produce. Every farmer must seriously consider the gravity of the occasion and after a careful survey of his conditions and circumstances see wherein he can do his bit for king and country towards meeting the demands for a larger and still larger output from his farm.

A dominion-wide campaign of education and inspiration was at once inaugurated by the several departments of agriculture and carried forward with earnestness and enthusiasm in every province from the Atlantic to the Pacific. Meetings of farmers were addressed, special bulletins of an educational character were written and widely distributed, articles on timely subjects appeared in the press, correspondence on matters pertaining to better farming was invited. This outlines the principal features of the campaign, in which the officers of the several departments of agriculture took a prominent part. This campaign in certain of its features is still being prosecuted. It has done and is still doing a great deal of effective work and the results are to be seen, I believe, in every province of the Dominion.

The harvest of 1915 was unprecedented in Canadian history. In its truly magnificent abundance it was a record-breaker. This we know was largely due to the exceptionally favourable seasonal conditions that prevailed in that year over the larger part of the Dominion and especially in the great grain-growing areas of the North-Western provinces.

Unfavourable weather conditions prevailed in 1916 over large areas in Canada both in the East and in the West, very materially reducing the agricultural output. It was a very trying year for the farmer in almost every part of the Dominion. In the East, continued and heavy rains prevented the getting in of the crops in good time—and it is seldom that late sown crops give even fair yields no matter how rich the soil may be, though we safely say that crops in a properly prepared and fertile soil will go far towards offsetting the disastrous influence of an untoward season. In certain sections of the prairie provinces, weather conditions induced an outbreak of rust—the most severe since 1904—and this most materially reduced the wheat output.

These two seasons, 1915 and 1916, emphasize the fact that weather, seasonal conditions, constitute a limiting factor in crop production, a factor that will always make agriculture as an industry more or less of a hazard. No matter how well the soil is tilled and cared for, no accurate prediction can be made of what the yield will be; the harvest alone will show the results of the year's labour. It is this consideration that supplies one of the chief reasons for advocating mixed farming, for this obviously must materially reduce the hazard.

But in this matter of results it is well to remember that agriculture compared with other industries is not one that can be readily or quickly "speeded up". In a very real sense it is the methods of the past that largely determine the success of the future, at all events, the immediate future. There are few soils that can be built up to their maximum productiveness in a season. Even with the adoption of the best methods the work of improvement is comparatively slow; soil deterioration, due to poor and irrational methods, unfortunately is much more rapid. We know there are thousands of acres in the Dominion that have not been brought up to their maximum productiveness, not even giving average yields, for the tendency in the past has been towards extensive rather than intensive farming—too many acres to thoroughly till with the labour and capital at the farmer's command. But we shall mend this as the years go by.

With live stock, meat products, dairy produce, the difficulties for immediate increased production are still greater. Many of the reasons for this will be obvious and I need only refer to one, that live stock needs labour—and the labour problem is without doubt the most serious and the most difficult to solve of all agricultural problems to-day. Its solution may be temporarily sought in some degree, by rearrangement of the labour of the country as a whole, by importing labour from the United States, and by the help that to some extent that may be drawn from our towns and cities.

The main purpose of this address is to give you some account of our propaganda, the teachings which, if followed out, might lead to increased production. I must not, of course, attempt to enter into detail which would only be of interest to an agricultural audience. I shall therefore confine myself to an epitome, emphasizing the more important features of the campaign.

In the first place I may point out that the principles of rational, successful farming remain the same, whether we are at war or dwelling in peace. Consequently we had nothing new of a fundamental character to propound, no panacea to advocate that would cure the ills of soils and crops and ensure large yields; no short cuts that would eliminate work

and bring success. We believe that successful farming and maximum production can only be achieved by the application of the teachings of science and practical experience and it was these teachings we wished to bring home to the farmer in the most forceful way possible.

And, secondly, I wish to say that while we urged that every available acre of suitably prepared land be put under crop, we urged still more strongly that the effort be made to obtain a larger yield from the acreage at present under cultivation. There is unfortunately too much room for improvement in this latter regard. Our crop yields in general are much below what is possible and we believed there would be a better result and more profit to the farmer in bringing up his yields than in extending his area under cultivation, although there are places where both may be possible and desirable. To this end we emphasized, primarily, the need of greater attention to methods of increasing soil fertility—drainage, more thorough tillage, more liberal manuring, the growing of leguminous crops, the use of fertilizers. Other matters were the fall preparation of the land, the importance of seed selection, the cultivation of the hoed crops to produce an earth mulch and thus conserve soil moisture for the use of the growing crop—and turning to live stock, their breeding, feeding and care. These then constituted the chief themes of our addresses and writings. To-night we can only rapidly survey those which have to do with the soil, and I have chosen them because of their fundamental character. But many of the other subjects are almost of equal importance.

SOIL CULTIVATIONS.

DRAINAGE.—Speaking generally, drainage is fundamental to the greatest measure of success. There are light and sandy loams underlaid by sand or gravel which need no sub or artificial drainage, but for clay loams it is essential for the best results, not merely to take away water in the spring, and allow early seeding, but to make the soil more moist throughout the season. No amount of surface tillage, no amount of manure or fertilizer can ensure maximum crop production on a poorly drained soil. Surface evaporation is slow in the early months of the season. Tile drainage is needed therefore that the heavier soils may be worked to advantage before the seeding time passes. Poorly drained soils are water-logged soils, and this means a condition absolutely injurious to growing crops, for the root system needs air. Crops can die of suffocation, even after they have got a fair growth. Poorly drained soils are cold and wet.

There are thousands and thousands of acres in the Dominion that need tile drainage before they can be made to do their best. It is

expensive work, but there is no farm operation that pays better in the long run. Wherever needed and funds permit, our farmers have been urged to put in drains.

TILLAGE.—The soil of our fields naturally settles down and runs together into a more or less compact mass, due largely to rains, and it is thus rendered unfavourable for seed germination and the easy extension of the root system of the crop. This condition must be ameliorated by ploughing, sub-soiling, the use of the disc, spring tooth and smoothing harrows and the roller. By these implements the soil is opened up and reduced again to a fine condition; it is aerated and warmed and made capable of holding moisture in a form available for the crop nutrition, known technically as film water. A "fine" seed bed is half the battle and therefore the preparation of the soil is of paramount importance; as the crop grows it needs a due supply of moisture—for all the food that it takes in from the soil must be in the form of a solution—and it is good tillage and subsequent surface cultivation that conserves this necessary moisture.

These observations will have made it clear that the soil, in addition to supplying plant food, must form a comfortable means for the support of the plant, a comfortable home in which the crop can live and thrive. It must be well aerated, moist and warm. Tillage is a generic term to include all those mechanical operations that bring about this comfortable condition, commonly known as good tilth. We are fortunate in this country in having many excellent farm implements for the tilling of the soil, implements specially adapted for their particular work. In this connection we look hopefully in the near future to the perfection of the motor plough, which will enable the farmer not only to cheapen, extend and improve his tillage but to take better advantage of those short periods, altogether too short in some seasons, when the heavier soils are in the right condition for working, neither too wet nor too dry.

Drainage and good tillage mean time, labour and expense, but they are indispensable for maximum crop production; there is nothing we can add to the soil that can take the place of its thorough preparation.

FARM MANURES.

In the whole economy of farming there is no subject of greater, of more vital importance than that of manure and manuring. To-night we can only touch upon some of its more salient features.

Obviously the amount of plant food in the soil which is present in a more or less available form is a prime factor in determining crop yields; therefore in this campaign we are urging our farmers to take every rational, economic means to increase its store. To this end farm manures

stand *facile princeps*. They constitute the basis of fertility for soils under cultivation; they are at once the most effective fertilizers and best "soil improvers" known.

The function of manure in the soil may be said to be threefold: the supplying of the three essential elements of plant food, nitrogen, phosphoric acid and potash: the inoculation of the soil with micro-organisms, bacteria, which give "life" to the soil and which prepare crop food from the store in the soil and are more especially useful in the development of the nitrates, the chief form of nitrogenous food for all crops other than the legumes; and lastly the physical improvement of the soil, making it mellower, warmer, better aerated and increasing its water-holding capacity.

Mixed manures, that is the excreta plus the litter, of average quality will contain approximately per ton, 10 lbs. of nitrogen, 5 lbs. phosphoric acid and 10 lbs. of potash, and such manure would be worth to-day for its plant food about $2.50 per ton. But from what has been said as to the several functions of manure we must ascribe to it a greater value than that calculated from its plant food content. The chief reason for this lies in the fact that it furnishes a large amount of humus-forming material. Humus is a very important constituent of soils, not merely because of its physical effect in mellowing soils and its large moisture-holding capacity, but because it is the natural storehouse of nitrogen, the most costly of all plant food elements; and because it furnishes the food upon which the soil bacteria thrive and develop. The colloidal properties of humus in holding mineral plant food that would otherwise be leached away to depths below the root system is also an important and valuable function.

Our virgin soils of extraordinary richness and fertility, as found for instance in the prairie provinces, are well supplied with this humus-forming material; soils exhausted by cropping and irrational methods of farming have been depleted of this material and herein lies their poverty, their low productiveness, for as the humus is "burnt" out, so the nitrogen of which it was the storehouse is dissipated. The humus content, we may therefore conclude, is a fair measure of the nitrogen content and of a soil's productiveness. Light soils lose their humus and nitrogen more quickly than strong heavy loans and therefore require more frequent replenishment with manure or other humus furnishing material to maintain their fertility. If time permitted we might well dwell at greater length on the functions of humus, so important is its rôle in maintaining soil fertility. Our campaign has endeavoured to emphasize the necessity of keeping the soil constantly and well supplied with this natural builder of soils.

Our doctrine then is that manure has no substitute—chemical, physical or biological—for maintaining and increasing soil fertility. The more manure the larger the crops, the larger the crops the more live stock that can be kept, the more live stock on the farm the more the manure. This means that rational farming is mixed farming and that mixed farming means increased crop production.

We may very briefly consider one or two of the more important phases of this manure question as emphasized in our campaign. First, the necessity of sufficient litter in the barn, stable, piggery, etc., to absorb and retain all the liquid excreta. This necessity has not been duly recognized on many of our farms, and thousands of tons of plant food in the most valuable form annually have been allowed to go to waste. As regards plant food, especially nitrogen and potash, the liquid is richer than the solid excreta and, further, these elements are present in a soluble and immediately available condition and hence more valuable than those in the solid excreta. If the supply of straw is short, sawdust, or air-dried peat or muck should be employed as supplemental litter. Peat and muck, of which there are many and large deposits in Canada, when air-dried possess a high absorptive capacity and have in themselves a manurial value of no mean importance. Hence their use in the way indicated increases not only the bulk but the value of the resultant manure. They can also be used in the making of valuable composts.

Nearly ninety per cent. of the total potash excreted by the animal is present in the urine. This fact alone would emphasize the value of the liquid excreta to-day, when the product of the Stassfurt mines, practically the world's sole economic supply of potash, is virtually unobtainable. Such small quantities of these potash compounds as remain on this continent are far too high in price to be used for agricultural purposes.

Then we are advocating the application of the manure to the soil while still fresh. This we have proved to be the most economic method in general farming, for the rotting of manure even under the best conditions is inevitably accompanied by some loss of organic matter and nitrogen. If the rotting manure is exposed, as in the barnyard or unprotected heap in the field, there are further losses by the leaching away of the soluble nitrogen and potash and these losses may be enormous. It is a conservative estimate that the losses from the careless management of manure amount to thirty per cent. or more of the initial value of the manure. Undoubtedly these losses throughout the Dominion represent annually many thousand dollars worth of plant food, needed all too badly for our crops.

Weight for weight, fresh manure has given yields almost equal to those obtained from rotted manure, in spite of the fact that the latter contain higher percentages of plant food. This has been proved by careful experiments at Ottawa conducted over a considerable number of years. The reason for this is rather obscure. Possibly it is due in part to the fresh manure inoculating the soil with desirable micro-organisms to a greater extent than does the rotted and in part to the greater warmth set up by the fermentation of the fresh manure in the soil and the heat so developed benefiting the crop in its early stages. Be that as it may, the fact remains that rotting manure in large heaps in the fields—a method which is still quite common—is very wasteful. In general farming manure has no greater value than at the time of its production; indeed we may safely say, for the average farmer its initial value is its maximum value and the quicker it can be got into the land the better.

If it is impracticable by reason of the depth of snow, or the condition of the land, to immediately spread the manure on the fields, the pile should be kept compact and moist, sheltered from the rain and unless heating takes place not turned. Manure made in loose boxes or pens, in which fresh litter as required is added and the manure allowed to accumulate under the cattle, is the best made on the farm, but this plan cannot be adopted for dairy cattle.

In the winter small piles of 500 to 800 lbs. can be made on the fields to be dressed. Over the greater part of the Dominion such piles freeze through solidly and lose but little of their value. They can be spread as soon as the snow disappears.

For teaming the fresh manure from the farm buildings and its distribution on the land a manure spreader should be used. It is an implement that saves labour and in distributing the manure more evenly than can be done by hand, does most effective work. Undoubtedly its employment means a more even crop and larger returns from the manure than were obtainable before its invention.

With the limited amount of manure usually at the command of our farmers it does not seem desirable to plough it under too deeply; if well incorporated with say the first five inches of soil it will by its fermentation warm the surface soil and increase its moisture holding capacity and thus serve to nourish and feed the young crop when it is least able to forage deeply for its food. It is seldom indeed that there is a sufficiency of manure on the farm to allow of more than one application in each rotation. To which crop then shall it be applied? We counsel that manure should be applied for hoed crops in the rotation—potatoes mangels, corn, etc., for thereby the greater return will be obtained.

The top dressing of impoverished meadows early in the season has also been found a profitable practice.

These then constitute some of the more important features respecting manure in our propaganda.

CLOVER, ALFALFA AND THE LEGUMES GENERALLY.

Though the fact that the growth of clover increased the yields of succeeding crops has been known since the days of the Ancients, the explanation of the fact awaited the discovery of Hellriegel and Wilfarth in 1886. These scientists showed that the leguminosae have the power to appropriate the free nitrogen of the air that is in the interstices of the soil, through the activity of certain bacteria that reside in nodules or tubercles on their roots. Their presence is an example of useful symbiosis. These bacteria pass on the elaborated nitrogen to their host for the development of root and stem and leaf. The immense value of a leguminous crop in the rotation must be at once obvious. The legumes alone of all our crops, leave the soil richer rather than poorer for their growth. Even when the crops are cut and used as fodder—and very rich fodder they make by reason of their high nitrogen content—the soil will be richer for their growth, because of the nitrogen in their root system. Experiments have shown that by the growth and turning under of clover, alfalfa and other legumes from 50 to 150 lbs. of nitrogen can be added to the soil per acre. And this enrichment is not in nitrogen only; it is in humus-forming material and in the mineral plant food therein held and which is set free for crop use as the organic matter further decomposes. Alfalfa with its heavy and deep root system stands first among the legumes in this nitrogen appropriation; red clover comes next. The manurial value of these leguminous crops is easily observable for three or four years, that is, throughout the whole rotation and, at a conservative estimate may be said to be equal to that of an application of five to ten tons of farm manure per acre. This fact has been established by repeated experiments. All grain crops in the rotation should be sown with clover or a mixture of grass seed with clover or alfalfa, for this method not only furnishes an abundant yield in the following season of highly nutritious fodder but manures and improves the land in a way and at a cost not possible by any other means.

It sometimes happens that the soil does not possess the nitrogen-fixing bacteria. In such cases, made known by the absence of nodules on the roots of the crop, inoculation must be resorted to. This is more especially necessary with alfalfa. Cultures for this inoculation may be obtained from the botanical laboratories of the Experimental Farm, or

soil from fields upon which the legume has grown luxuriously can be procured and applied.

The manurial properties of clover and other legumes has been worked out in a long series of experiments and the results have been of inestimable value to Canadian agriculture. In this campaign we are again emphasizing the main facts brought out by this investigational work, with the object of inducing our farmers to grow more clover and alfalfa, both for the production of a highly nitrogenous stock feed and for the enrichment of their soils.

LIMING.

Closely associated with the subject of the successful growth of the legumes is the question of liming. Leguminous crops will not thrive on a sour soil or one deficient in lime. Some soils are naturally deficient in available lime, some have been rendered so by cropping. The presence of lime is an indication of fertility and productiveness. Its functions are many. It promotes nitrification by neutralizing acidity; it improves the tilth of both heavy and light soils and it furnishes plant food. A bulletin has been issued that deals fully with all the important phases of this important question and our farmers are urged to ascertain, as is possible by quite simple means, if their land is in need of this element.

Ground limestone is now being used on many farms as a soil ameliorant with excellent results and we believe its employment in Eastern Canada and British Columbia will very largely increase in the near future. Our experiments in many districts in Ontario, Quebec and the Maritime Provinces have shown that lime or ground limestone is needed and can be profitably employed for increasing crop production.

COMMERCIAL FERTILIZERS.

In all that has been said so far respecting the means of increasing crop production, the call has been, more particularly, for more careful, more thorough methods of farm and soil management and though these entail labour they do not necessarily involve the employment of extra labour, which of course would mean an additional cash outlay. The case with Commercial Fertilizers is different: they must be purchased and unfortunately their cost to-day is higher than in ante-bellum days. Their use involves a distinct and direct cash outlay and the farmer, in their employment, must be fairly confident, not merely of an increased yield but of a profitable return; the increase in yield must be more than sufficient to pay for the fertilizer. The hazard is, of course, always

present, but there should be a reasonable expectation that with a favourable season there will be a profitable return.

Fertilizers are materials that furnish in more or less available forms one or more of the three so-called essential elements of fertility—nitrogen, phosphoric acid and potash. A fertilizer that supplies all three is known as a "complete" fertilizer. They may be chemical compounds, as nitrate of soda, sulphate of ammonia, etc., or they may be of organic origin, such as bone meal, guano, dried blood, tankage, fish scrap, etc. Frequently the compounded fertilizer as manufactured and sold under brand or trade name is made up of or is a mixture of both classes of materials. The Fertilizer Act compels the manufacturers to brand all this class of goods with the percentages of nitrogen, phosphoric acid and potash contained and also stipulates that the amount of available phosphoric acid should be stated.

Due largely to advertising and the activity of fertilizer agents, but also in part to the ignorance of our farmers respecting the nature of the several constituents or ingredients of fertilizers and the fact that these ingredients cannot at all times be readily obtained, the habit in this country has been to purchase the manufactured, compounded fertilizers, the price of which is usually from 15 to 40 per cent. above the cost of the ingredients.

Our campaign in this connection has therefore been one primarily of education; the instruction of the farmer regarding the functions of the several fertilizing elements in the vegetable economy, the special requirements of the several crops and the deficiencies likely to characterize different types of soil. Then we have pointed out the economy of purchasing the ingredients rather than the compounded fertilizer and given simple methods of home mixing and application. To tell all this in detail would be quite impossible to-night, I shall therefore merely bring before you as concisely as possible some of the more important deductions from our investigational work with fertilizers, since these deductions have been given out as a working guide for those employing these aids to increase crop production.

First, we teach that fertilizers have a legitimate, rightful place in a rational system of farming but that profit from their use seldom results if that place is not clearly understood. It seems to us important that the farmers, at the outset, should know our attitude towards fertilizers, for their are many views abroad in the country respecting them. There are those of the old school still in the land who consider fertilizers to be in the same class with quack medicines, that they act merely as stimulants, as a whip to a tired horse, and that no real benefit or profit results from their use. The number of these persons is happily on the decrease.

And there are those—almost as ignorant of the principles of agricultural science as those just referred to—who argue that if fertilizers are a source of available plant food, all that is necessary is to apply them generously and we must obtain increased crop yields. There is an element of truth in both view points, but taken as working hypotheses both are false and wrong. We are endeavouring to give our farmers information respecting the functions, uses and limitations of fertilizers from a sane and scientific standpoint. Fertilizers are no panacea to remedy the evils of poor farming, but they can be so used as to increase the farmer's profits. The advocacy in this war-time campaign, of a large and practically indiscriminate employment as urged by some well meaning persons, would I am sure be fraught with failure and loss.

We begin, then, this study of the profitable use of fertilizers by a consideration of the factors that limit crop growth, other than that of available plant food. First, are the conditions that are under our control so favourable that the fertilizer can perform its function of nourishing the crop? The nature and physical condition of the soil, its moisture-holding capacity (dependent on texture and humus content), its degree of aeration, its drainage, etc., are to be considered. Next, the seasonal conditions of the district likely to prevail are to be taken into account, the distribution of rain, the temperature, the hours of sunshine, etc. The probability is that over the larger part of the Dominion seasonal conditions are the most potent of all the determinative factors in crop yields.

And, lastly, there is the nature of the crop, its special requirements, its inherited capacity for growth and reproduction. All these factors have an important bearing on the scheme of fertilization, profoundly modifying the influence and effect of fertilizers. We cannot now stay to elaborate these factors, but one or two illustrations may be given to emphasize their rôle and importance. Remembering that the soil must be a comfortable habitat for the crop's root system, well aerated, moist and mellow, what opportunity has a fertilizer to play its part successfully in nourishing the crop in a stiff, heavy, plastic, undrained clay? Or, again, if the light and sandy soil, deficient in humus, dries up with a few days' drought, how can fertilizers feed the crop, for plants can only absorb their soil plant food in a soluble form? If there is danger of early autumnal frost, the fertilizing scheme must be towards hastening the ripening of the crop. And, lastly, if we are sowing a variety of oats the prolificness of which is measured by say, forty bushels per acre, can we make it yield sixty bushels by simply feeding the crop? Thus, soil, season and seed must all receive attention if the fertilizer application is to be rational and with a fair expectation of profits.

We may now proceed to some of the more important conclusions reached by us in our fertilizer investigational work during the past twenty-five years.

THE PRAIRIE PROVINCES.—Particular interest attaches itself to possibilities of increasing wheat production in Manitoba, Saskatchewan and Alberta by the use of fertilizers. A study of our results would not justify us in the prediction that this could be profitably brought about by a general application of fertilizer. For ten consecutive years, 1900–1909, we had a series of fertilizer experiments on the Experimental Farms at Brandon, Manitoba, and Indian Head, Saskatchewan. The series contained plots dressed with nitrogen, phosphoric acid and potash, singly and in combinations of twos and threes. The results, taking one year with another, failed to indicate any material increase in the yields of the fertilized over those of the unfertilized plots. Frequently the latter gave the larger crops, but it was seldom that the difference between the plots exceeded the amount that might be attributed to experimental error. Certainly there was no consistent increase due to any fertilizer and in no case was the increase sufficient to cover the cost of the fertilizer. These soils, it must be admitted, were typical wheat soils of high quality, but they were in no way exceptional. Hundreds of thousands of acres equally good are to be found in all three of the Prairie provinces.

Experiments carried on in northern Saskatchewan and northern Alberta likewise failed to indicate any specific deficiency in plant food in the soil, the results being irregular and the increases on the dressed plots (when such occurred) not being of that magnitude to warrant definite conclusions as to the virtue of the fertilizer employed or the expenditure for the purchase and application.

With respect to the future, my opinion is that the time will come when phosphates will be found useful. My reason is that of the three essential elements these western soils are least rich in phosphoric acid and that the extensive grain growing will tend to diminish the store of this element that is more or less available for crop use. Moreover, phosphates may be found of value in inducing an earlier ripening of the crop—a matter of much importance in districts where early autumnal frosts endanger the wheat crop. Our hope for these western provinces is that the abandonment of exclusive grain growing and the adoption of mixed farming and of rotations will serve to maintain fertility and obviate the necessity of relying generally on fertilizers for the up-keep of fertility. At the present time I feel assured that the determinative factors in crop production in these regions are the seasonal conditions. If our northwestern lands are not to be allowed to deteriorate, mixed

farming must be introduced, their fertility cannot be maintained by fertilizers. Above all it is imperative in the highest degree that the large humus content be kept up, be constantly replenished, not only to keep fibre in the soil that will prevent loss from "blowing" and "drifting", but to maintain the present high capacity of the soil for holding moisture.

With respect to British Columbia our investigational work has been carried on chiefly at Agassiz, eighty miles from the coast, and on Vancouver Island—the soils being light and gravelly in nature. The most profitable results have been obtained on potatoes, mangels and corn, and emphatic evidence as to the effectiveness of a complete fertilizer application, in conjunction with manure, for these crops has been accumulated. In the larger number of instances the fertilizer yielded a substantial profit. One of the most profitable formulae was nitrate of soda, 100 to 150 lbs.; superphosphate, 300 to 400 lbs.; and muriate of potash, 100 to 200 lbs. per acre. It would seem from our work that a profitable result from the judicious use of fertilizers may be expected in many parts of this province, especially on hoed crops, and we may look for a large and increasing employment of these aids to production in that part of the Dominion.

As regards Ontario our work has been confined to Ottawa, and therefore is only strictly applicable to the eastern part of the province. Very briefly it has shown that fertility cannot be economically maintained and profitable yields obtained by the exclusive use of fertilizers. The results, however, afford satisfactory evidence that fertilizer may be used to good advantage in conjunction with farm manures in a good system of rotation that furnishes humus to the soil, as in the growing of clover. This is probably true of all Ontario and Eastern Canada generally. The deduction is that when manure is scarce or has to be purchased at a high price it will be profitable to apply fertilizers, not to take the place of manure but to supplement its use. No special deficiency has been noted in the soils, a complete fertilizer, as a rule, giving the largest return.

Basic slag has proven the most useful phosphatic fertilizer on sour soils, heavy clays, on soils naturally deficient in lime and on peat and muck soils, while superphosphate on the lighter soils rich in lime has given the quickest returns, especially for turnips and cereals. Basic slag has frequently proved beneficial to old pastures, increasing the yields and improving the nutritive value of the herbage.

A top-dressing of nitrate of soda, applied in the earlier weeks of growth, has been found beneficial to grass, particularly when intended for hay.

Potash has not proved remunerative on heavy clay soils, but on many light loams it has given a good return, for encouraging the growth of clover, potatoes and leafy crops generally. Muck and peaty soils are improved by this element. No potassic fertilizer has proved more valuable than good hardwood ashes, and this is the chief home source of this element which we can now rely on, as the German potash salts since the war cannot be purchased save at prohibitive prices.

THE MARITIME PROVINCES AND QUEBEC.—By far the larger amount of our experimental work with fertilizers in recent years has been carried on in the Maritime provinces. It is quite evident that there is in these parts of the Dominion a larger and more lucrative field for fertilizers than in Ontario, not simply as we might suspect from poorer soils, but from the fact that the crops upon which they are used in these provinces are more particularly money or cash crops—potatoes, apples, etc. Upon such crops the prospect of a remunerative response is greatly enhanced, for the maximum gross returns are larger than, for instance, in grain growing. It is also probable that taken as a whole the seasonal conditions in the Maritime provinces are more favourable to the fuller use of the fertilizer by the crop, than in Ontario.

It is satisfactory to note that the deductions from our experiments at Ottawa, already stated, hold good in the main for Eastern Canada. Invariably the more lucrative response from fertilizers is on land rich or fairly rich in humus, the fertility of which is kept up by manure and the growing of clover. These means are indispensable for the profitable employment of fertilizers.

The largest profits have not always been obtained by what might be termed excessive applications of fertilizer, say 1,000 lbs. and over, but usually from a combination of manure with a moderate dressing of say 500 to 800 lbs. of a well-balanced complete fertilizer. These results have been confirmed at many points and in different seasons. It is quite true, however, that larger applications can be used with profit in the Maritime provinces and British Columbia than in Ontario. Potatoes are the principal crop to which the fertilizer is applied, the land being under a three or four year rotation.

Summing up this teaching with respect to fertilizers, we conclude that the exclusive use of fertilizers will neither keep up the fertility of the soil nor yield profitable returns; that it is on soils of medium rather than poor quality that a lucrative response from their employment is to be expected; that they can profitably be used to supplement the home source of fertility, farm manures; that the largest returns are not necessarily from the largest applications and, lastly, that it is on the money crop of the rotation, such as potatoes, that their application is most profitable.

The employment of fertilizers in Canada has been to date a very small matter compared with that in some other countries in which the soils are lighter and poorer than ours, but this use will assuredly increase. It cannot be otherwise with the adoption of intensive methods, the larger returns for farm produce, the increase in the price of land and the establishment of larger, better, steadier markets at home and abroad for farm produce.

In this account I have said nothing of that part of our campaign that has dealt with the choice of crops, with live stock—their care and feeding. These matters, of almost equal importance with that of crop production, have received the attention they merit. Practically every phase of farm life and work has been dealt with, but time to-night has only permitted me to bring before you in outline our teachings in this fundamental proposition of increased crop production.

At the outset of this address I said that this campaign to our farmers was one, not only of education, but one in which the men on the land were called upon from patriotic motives, as members of the great British Empire, to do their very best in these troublous times for their King and Country. They have been impressed with the fact that a great responsibility rests upon each one of them to put forth every effort possible towards increasing their farm products. As their lot is no easy one in ordinary times and doubly hard now that labour is so scarce, words of encouragement and inspiration have been spoken. Farmers are a hard working class under ordinary circumstances, now they are called upon to do a little more, work a bit longer and a bit harder. They need our sympathy and encouragement.

But there is no need to dwell at length on this phase of the campaign. I cannot do better in closing than quote from an appeal by Lord Selborne, President of the Board of Agriculture and Fisheries, to English farmers for an increase in the food production from the land. His words were direct and struck the right chord and they are as applicable in the Dominion of Canada as in the old land. He said: "You have something more on your shoulders than your own business to-day. You are no longer individual farmers making your own fortunes or losing them. You are trustees on your own land to do your best for England. You have your duty quite as clear and as definite as the captain of the cruiser or the colonel of a battalion. England has a claim on you farmers, men and women of every class, as clear as she has on our sons and husbands to go and serve in the trenches". These surely are inspiring words and clearly state the imperative duty of every farmer in the British Empire in these days.

THE GROWTH OF ETCH-FIGURES

By William Harvey McNairn.

PAGE

Introductory. 231

I. Experimental:

1. Corrosion of Colemanite. 232
2. Acid corrosion of spodumene. 238
3. Alkaline corrosion of spodumene. 341
5. Acid corrosion of diopside. 243
   (*a*) pits on the prisms. 243
   (*b*) pits on the clinopinacoid. 244
   (*c*) pits on the orthopinacoid. 247
   (*d*) pits on the orthodome. 249
   (*e*) pits on the base. 250
6. Alkaline corrosion of diopside. 250

II. Theoretical:

1. Introductory. 251
2. The point of origin. 251
3. The growth of the pit. 254
4. The nature of the figure-faces. 256
5. The beaks. 261
   (*a*) the nature and classification of beaks. 261
   (*b*) the crack beaks. 261
   (*c*) the normal beaks. 262
   (*d*) the tubular beaks. 263

THE GROWTH OF ETCH-FIGURES.

By William Harvey McNairn.

Introductory.

The extensive and ever growing literature which contains the results of investigators who have made use of the method of etching in order to obtain a more exact knowledge of various phases of crystal symmetry, is an evidence of the importance of this series of phenomena as a means of crystallographic research. Among these publications there have appeared from time to time papers which have been devoted to the study of etch-figures themselves rather than to their secondary application. It is evident from a study of these articles that many of the processes involved in the origin and growth of etchfigures have not yet been fully explained, and as these processes are intimately connected with the molecular structure of crystalline matter, the value of fuller information will readily be conceded.

A leader in the group of investigators who have devoted themselves to this phase of the subject is Professor V. Goldschmidt of Heidelberg, who published some years ago, two papers, among others, embodying a new theory for the formation of etch-figures.[1] According to this, both pits and etch-hills are the result of movements developed in the solvent. The chemical action between the corrosive and the substance upon which it is acting, gives rise to currents, some of which are directed towards and some away from the surface which is being etched. The interference of ascending with descending currents tends to form eddies, each of which is the starting point of a pit. The tendency of any solvent would be to produce regular, hemispherical excavations, but this is offset by the force of crystallization, which constantly endeavours to keep the corroded surfaces bounded by crystal planes. The resultant of these opposing tendencies is the typical etch-pit, whose sides are neither wholly irregular, nor yet normal crystal faces, but, as a compromise, planes of similar nature to vicinal faces. When a beginning has been made, the growth of the pit proceeds at a diminishing rate, and since the edges of the pit dissolve with greater rapidity than the walls, the natural result will be an increasingly indistinct outline and walls,

[1] Zeitsch. für Kryst., 38:273, 656. 1904.

which finally become practically indistinguishable from the surface of the crystal face. Then, newly developed eddies may form a fresh lot of pits in the enlarged bottoms of the old ones, and so the growth goes on.

At first sight the explanation of the phenomena of etching offered by this theory seemed to be quite adequate, but some facts which came to light in the course of an investigation made by the writer, of the symmetry of diopside seemed to point so clearly to a cause which lies much closer to the molecular structure of crystalline matter, that the present research was undertaken in order to attain to a fuller knowledge of these interesting and somewhat obscure phenomena. To this end it was necessary to devise special methods of investigation. In the first place, in order to observe the origin and subsequent stages in the growth of the pit, and to compare the rapidity of the action on the various faces of the crystal, it was exposed to successive, short applications of a corrosive in somewhat dilute form. In the second place, in order to trace these stages with greater certainty, the corroded crystal was examined at each step by means of the goniometer, and in the third place in order to study the distribution of the pits a series of parallel cleavage plates was etched. By these methods, the various stages in the growth of an etch-figure could be traced from a shapeless, shallow depression, through the next stage of the greatest perfection, with almost flat figure-faces which approximate true crystal planes, and finally, to the gradually disintegrating pit, whose sides become shallower and rounder until the whole disappears.

In order to observe these stages of growth various monoclinic minerals were etched. Colemanite, spodumene and diopside, on account of their transparency, their perfect cleavage and the ease with which satisfactory pits could be produced, were found to be the most suitable. The material was supplied by the Mineralogical Laboratory of the University of Toronto, where most of the experiments were carried out under the supervision of Professor T. L. Walker.

PART I—EXPERIMENTAL.

1. CORROSION OF COLEMANITE.

In several ways colemanite was found to be particularly well adapted to these experiments. It is obtainable in clear and transparent crystals and it has a perfect cleavage parallel to the clinopinacoid. It is thus possible to prepare plates so thin that the effects of corrosion on opposite sides can readily be observed and compared, and whose broad faces are

those which exhibit the maximum cohesion. Experience has shown that the most perfect examples of pits are produced upon such faces. This has already been observed by Baumhauer, who presents the facts in the following words: "Am besten entstehen die einzelnen Aetzeindrucke auf solchen Flächen, welche nicht allzu leicht vom Aetzmittel angegriffen werden, welche demselben also einen verhältnissmässig grossen Wiederstand entgegensetzen. Dies ist haüfig der Fall bei Spaltungsflächen"[2]. This necessarily follows from the fact that the phenomena of etching as well as those of cleavage are dependent upon the cohesion of the crystal.

It is a well-known fact that strikingly different results are obtained by the use of various corrosives, and so it is important to choose with care that one which is to be employed. In these experiments with colemanite three acids, each in a very dilute form, were successively tried, namely citric, acetic and hydrochloric.

Citric acid produced etch hills. In cases where the solution was very dilute and the action had been early discontinued, the surface of the cleavage plate was covered with closely lying hills of polygonal form, fitted together like tiles in a pavement. As the process progressed, certain of the hills became undercut leaving an overhanging part somewhat resembling the beaked extensions of pits to be subsequently described. Frequently these projections, all pointing in the same direction, had the appearance of being oriented.

As a result of many experiments to determine the effect of the corrosive in various degrees of dilution, it was found that with extremely dilute acetic or hydrochloric acid, the pits were very small, and that with corrosives of greater strength the pits became larger. A 0.5% solution of glacial acetic acid acting on the clinopinacoid, produced great numbers of four-sided pits so small that it required the highest available power of the microscope to observe their details. Along with these well-defined pits there were also shallow depressions with indefinite outline. Some of these had a deeper part which approached somewhat tc the form of a pit. An interesting feature was the occurrence in almost every clear pit, of a beak-shaped extension, sometimes many times longer than the pit itself, growing from the deepest part of the figure. As solutions of greater strength were used, the percentage of beaked pits grew steadily less, and the beaks became shorter, until, when the optimum strength was reached, they were practically absent.

---

[2] "Die Resultate der Aetzmethode in der krystallographischen Forschung." Leipzig, 1894, p. 3.

When a solution of double the strength was used, that is 1.0%, results were obtained which differed only in degree from those already described. The pits were larger, the beaks were shorter. The ill-defined figures mentioned in the previous paragraph were not observed, but each pit was surrounded by a shallow depression in which it seemed to have been developed (Plate XXVI, fig. 1). A curious feature noted here was that the beaks of two adjoining pits had become united, forming a connecting tube (Plate XXVI, fig. 2). It was noted also that the pits were not evenly distributed, the surface of the crystal being in some places closely covered, and in others comparatively free. The significance of this phenomenon, which has been frequently referred to by previous investigators, and which will be more thoroughly discussed on a later page, forms the basis of one of the main deductions of this paper.

Stronger solutions gave larger, clearer pits and still shorter beaks. When 2% had been reached the pits were still very minute, and those on one side appeared to differ from those on the other in their rhombic outline, being more nearly lozenge-shaped. Distorted pits, enclosed by four non-parallel sides, two of which were distinctly longer than the others, were frequently seen.

In consequence of the fact that, with colemanite, hydrochloric acid acts much less vigorously than acetic acid, the action of the former was more readily controlled and the results were correspondingly more satisfactory. It was found that a 1% solution gave pits which were much more primitive than those in the experiment previously described, in which a solution of acetic acid of half the strength was used, and there was the advantage that the pits were somewhat larger. Under these conditions there were produced numerous small, shallow depressions, whose sloping sides lacked the definiteness of figure faces. In most cases the depth was greater in one part, and set within was a clearly defined pit. (Plate XXVI, fig. 3). We shall see that a similar primitive form was met with in the investigation of the figures on diopside.

At this point, use was made of the method of exposing the crystal to the intermittent action of the same corrosive. After the first exposure to a 2% solution the surface was found to be covered with shallow, lozenge-shaped, asymmetric pits, set close together in parallel arrangement (Plate XXVI, fig. 4). There were no beaks. The pits observed after a second exposure had steeper sides (Plate XXVI, fig. 5). Some of these may have been the result of further development of the previous forms, but a few at least were new figures growing upon the sloping sides of the earlier ones. While further action resulted in the dissolving away of the etched surface in most cases, it was observed that here

and there the old centres of action remained and the pits grew downwards into the substance of the crystal (Plate I, fig. 6). Alongside of these there occurred great numbers of minute pits of a new generation and a new quadrilateral form somewhat like the typical pits on the clinopinacoid of diopside to be described in a subsequent section (Plate I, fig. 7). Some of these, it should be remarked, had rudimentary beaks. Subsequent action did little more than slightly increase the size of the pits already formed, and after the seventh test it was finally discontinued.

Since Baumhauer, in the article already referred to in these pages, had spoken of the occurrence of beaked pits, a phenomenon not observed in these tests in which dilute hydrochloric acid was the corrosive, a new series of experiments was designed to determine whether they could be obtained by using solutions of greater concentration. Three solutions were accordingly prepared containing respectively 4, 6 and 8% of the acid, and each was allowed to act upon a cleavage fragment. In the first case the comparatively large, four sided pits produced, although their general outline was typical for the clinopinacoid, were lacking in the full symmetry in having their deepest part asymmetrically located (Plate XXVI, fig. 8). When the strength of the solution was increased to 6%, still larger and clearer pits were produced, some of which had fine, hair-like beaks (Plate XXVI, fig. 9). In an 8% solution very clear, straight sided pits were formed but stronger solutions resulted in pits of less distinctness. Evidently a corrosive of medium strength is the most likely one to produce beaked pits.

From time to time pits had been observed which were characterized by minute extensions somewhat resembling beaks, but growing out from one of the angles of the pit and not from the bottom. When a 10% solution was used this phenomenon was strikingly evident. On a careful examination, the projection was seen to consist of a narrow crack running downwards from the surface of the crystal face in such a way as to appear like an extension of one of the side faces of the figure. Similar pit formations as observed in other crystals will be referred to in a subsequent section of this paper.

One group of these experiments was designed to throw some light upon the problems of the point of origin of the pit. It will be remembered that Professor Goldschmidt had suggested that each pit indicates the place where currents have started in the corrosive, and that the growth of the pit is the result of the continuance of these currents. It was observed however that characteristic corrosion was obtained in the foregoing experiments, even when the test tube was vigorously shaken. Further, remembering that in the process of electro-metallurgy, similar

currents are avoided by keeping the solution in constant motion, the effect was tried of directing a small jet of the corrosive against the crystal and then quickly stopping the action by plunging it below the surface of water. Under these conditions no ascending current of sufficient force to overcome the jet which was being directed against the crystal could have been formed, and yet clearly defined pits, though small ones, were produced.

It becomes quite evident that we must look for some other explanation for the origin of pits. When we examine an etched crystal we cannot help noticing that the pits are not scattered evenly over the surface, but that some parts are comparatively free and some densely covered. This fact had already been observed by Baumhauer,[3] who remarks: "Die Vertheilung der Aetzfiguren über die geätzte Fläche ist nie eine gleichmässige, wie man nach der Theorie erwarten sollte".

Tentative explanations for this irregularity have from time to time been brought forward, and as this problem includes the fundamental one of accounting for the origin of the individual pit, it was necessary to devise experiments to put the various theories to practical tests. Several fragments which had been marked with fine scratches were etched, but instead of the etch-figures being more numerous over the scratches, the latter were at once smoothed away by the corrosive. It had been suggested that possibly small particles of dust might provide the corrosive with points of attack, and that the fortuitous scattering of the dust particles might reveal itself in the apparently unaccountable distribution of the pits. In order to test this several pieces which had been covered with dust were exposed, but in no case was there any increase in the number of pits, or any concentration on that part of the surface where a greater amount of dust had collected.

Another possible explanation for this bunching of the pits was that the crystal might have been under strain, but a careful microscopic examination of several very thin slices from crystals which had shown this concentration of pits, failed to give the irregular extinction under crossed nicols, which is to be expected in strained crystals. This is of course what one might have expected, since pitting is a function of the cohesion of a crystal and strain is the result of abnormal elasticity.

Among the crystals used in these experiments some were transparent while others were translucent. The transparent crystals, in some cases at least, produced large and clear pits, which were not set very closely together, while the surface of the milky crystals was closely covered with small, indistinct pits, making the crystal still less transparent.

---

[3] op. cit., p. 6.

This milkiness was found to be due to the presence of numerous small inclusions. There would thus appear to be some connection between the number of pits and the number of inclusions, and it seemed quite possible that the uncovered top of an inclusion might form a ready point of attack of the corrosive. But, while in a given experiment the pits are of approximately the same size, the inclusions on the other hand vary, some being many times the size of the largest pit. Further, it was found that the places where most pits were produced were not the areas of the greatest distribution of the inclusions, and finally, in no case was an inclusion seen to be the starting point of a pit. We may safely conclude then that the relation between inclusions and pits is not that of cause and effect, but rather that of a common origin. The ability of a growing crystal to take up impurities from the surrounding solution, and the frequency of the occurrence of possible points of attack for the corrosive on the faces of a mature crystal, alike depend upon abnormalities in its cohesion.

An observation of Baumhauer's in his paper on the apparently anomalous pits of colemanite, when more fully worked out, gave a clue to the elucidation of this problem. He found that if the two cleaved halves of a crystal which have been subjected to the action of a corrosive, be placed together in their original position, pits on the two halves will be found to coincide and thus form a negative crystal, which is divided, sometimes in the centre, but more frequently unequally, by the plane of cleavage. The bearing of this phenomenon upon the problem of the origin and cause of pitting, was not discussed or suggested by this investigator.[4]

Following this experiment, a piece of the mineral was cleaved into halves, which were then etched separately, but under similar conditions. It was found that the size, number and distribution of the pits on adjacent sides of the plane of cleavage were quite similar, and even in some cases complementary pits could be identified. But the distribution of pits on opposite sides of the same fragment was always different, and sometimes a difference was also observed in their size and development and even in their shape.

A suggestive fact which came to light in this experiment was that the negative crystal which would be formed by bringing the two pits on adjacent faces together, was not divided symmetrically by the cleavage plane. The deepest part of one pit will then be found opposite the shallowest part of the other. In fact the two pits are enantiomorphous

---

[4] Zeitsch. für Kryst., 30: 97. 1889.

(Plate XXVII, fig. 36). It would appear that this fact has a bearing upon the grade of symmetry of the crystal.

---

2. ACID CORROSION OF SPODUMENE.

In order to obtain etch-figures upon the prismatic faces of spodumene, a small cleaved fragment was exposed to the action of concentrated sulphuric acid and fluorite over a low bunsen flame. After an exposure of five minutes no result was visible, but when the same fragment had been subjected to an additional exposure under the same conditions for ten minutes longer, numerous, clearly defined pits were observable. Of these primitive pits three types were noted which were bounded by three, four and five sides respectively. The triangular form appeared to be the youngest.

These typical primitive pits were each bounded by one short, straight side and two larger, curved ones (Plate XXVI, fig. 10). The angle *B A C*, which contained the deepest part of the pit, was read in one sharply defined example as 80° 48′. These pits were shallow and gave no indications of figure faces, but were simply slight depressions deepening towards one corner. Along with them were others which, judging from their depth and distinctness, were somewhat more mature. In them the sides had increased in number to four, and were no longer curved but straight. Instead of being mere shallow depressions, these pits were enclosed by four definite figure-faces, two being unequal scalene triangles and two unequal deltoids (Plate XXVI, fig. 11), but even yet the structure was somewhat lacking in clearness. It will be noticed that they could be produced from the pits of the first type by truncating the angle *B A C* by the line *D E*. In addition to these two forms, there were a few which at first appeared to belong to another group characterized by a five-sided outline (Plate XXVI, fig. 12). These may, however, be considered as derived from the four-sided pits by a further replacement of the angle *B C A* by the line *G F*. None were observed of a shape which would suggest the replacement of the angle *A B C*. It will be seen then that the three main types of pits produced upon the cleavage face of spodumene may be looked upon as variants of the same primitive type, and further, as representing thre stages of growth through which the individual pit would pass if conditions were favourable.

Along with these occurred some examples of a fourth type which had a more distinctive appearance, owing to the occurrence of beaks. This has been supposed by some investigators to have a bearing upon the question of the grade of symmetry shown by the crystals of this mineral and others, especially diopside and colemanite. They are

illustrated in Plate XXVI, fig. 13. It will be remembered that in the most primitive type one corner, that near the point *A*, was always deeper than the rest of the pit. In some instances this deepening was very pronounced, occasionally even being prolonged into a knob (Plate XXVI, fig. 14). The beak, whenever present, extended from this corner. Finally in some instances pits had been formed which appeared to be composed solely of the beak enormously developed. To so great an extent had this occurred in a few cases, that a tube had been produced which apparently ran along parallel with the surface, and emerged again at a considerable distance in another small pit. This resembles what we saw in the etching of colemanite, in which small pits were joined by a connecting tube, but in the latter case they were larger and more clearly defined.

It will be seen that the pits thus developed on the cleavage face of spodumene are of considerable diversity. All of these however may be considered, from the circumstances under which they were produced, to be comparatively young, and in order to have examples of a more mature type, another fragment of the crystal was exposed to similar corrosion conditions for a period of thirty minutes. After this somewhat lengthy exposure there was found a series of pits of various stages of development. While some of them gave evidence of a greater maturity there were still others which resembled that previously described as apparently the most primitive type. This suggested the idea, which further experiments showed to be the correct one, that as corrosion continues not only are the existing pits deepened and matured, but new and immature ones are constantly coming into existence.

The most distinct of these forms consisted of a shallow, triangular depression, differing from that observed in the specimen etched for fifteen minutes in being bounded by straight lines (Plate XXVI, fig. 15). The outlines seemed to be those of a right-angled triangle, but on measurement the angle *A B C* proved to be 96°, while the angle *B A C* was 53° 27′. Other less definite examples of this form gave values for the more obtuse angle of 105° 24′ and 112° 7′ respectively. This may be looked upon as a modification of the form first described, but differing from it in its deepest and best developed part lying between the sides *B A* and *B C*. Some of the figures, by their size and distinctness indicated a still greater maturity. Not only were they very much deeper, but two of the three sides appeared to cut perpendicularly, while a third sloped gradually (Plate XXVI, fig. 16). In fact, in some of the examples the steeper sides seemed actually to overhang. This formation of an overhanging edge, a peculiarity which will be referred to later, is a rather unexpected phenomenon. Goldschmidt draws our attention to

the fact that the action of solution will take place with the maximum of rapidity on any edge, more particularly if that edge is at all acute, and in this way the pits become flatter as action continues. But here are examples of the persistence of a well defined and sharp edge.

Along with the forms described above there were others which from their distinctness of outline and depth would appear to be somewhat more mature still. They were bounded by three unequal, triangular figure faces of which the largest was curved. An additional peculiarity was that which has been referred to in the previous paragraph: the deepest part was not in the centre of the pit but was very much to one side, being in fact under an overhanging edge. In all the pits of this type, the figure-faces appeared to be striated parallel with the surface of the etched face. The significance of the phenomena just described will be dealt with in a subsequent part of this paper.

Pits of a still more mature form were obtained by exposing the specimen to the corrosive action of the commercial solution of hydrofluoric acid. After ten minutes' heating over a water bath the corrosive had produced, not the forms which we usually think of when we speak of pits, but fine tubes. The openings to these tubes were larger than the tubes themselves and to a certain degree resembled true pits. On continued action they increased in a remarkable manner, not only in number, but also in length, becoming twisted and interwoven like a bunch of hairs. The growth of these tubes continued with further exposure to the corrosive long after the surface originally acted upon had been completely dissolved away. After an exposure of fifty minutes when the action was discontinued, some of the tubes seemed to have penetrated nearly half through the fragment. This rather extraordinary result seems to have a bearing upon the nature of schillerization as will be seen from the discussion in the second part of this paper.

In the experiment described above, in addition to the corrosion which produced the fine tubes in the interior of the crystal, another and different type was observable on the surface. Gradually the pits which were first formed enlarged their borders until by the coalescence of numerous flat bottomed pits the whole surface with the exception of a few residuary etch-hills had been removed. On these freshly formed surfaces new etch-figures began to appear. While they were still of a somewhat triangular form, being composed of three figure-faces, one long and shallow, a second slightly shorter and steeper and a third small, steep and triangular, yet they showed considerable variation from the first crop produced upon the unetched face. After an exposure of thirty minutes they were fairly large, of clear general outlines but the form of the figure-faces was not easily seen. After forty minutes

they had become not only more numerous but also more clearly defined, and by fifty minutes they were quite mature and distinct. This series of reactions is of interest when considered in connection with the experiments above described, in which adjacent sides of cleavage fragments were simultaneously etched. It would appear that the distribution of pits is determined by the molecular conditions of the crystal face, and that after the whole layer has been removed by corrosion, a new layer with new possible centres for pitting, is brought to light. The significance of these facts is more fully discussed in the second part of this paper.

Two slight irregularities in the form and arrangement of the pits remain to be noted. Greim, in describing the somewhat similar figures on diopside, remarked that the position of the positive and negative hemi-pyramids could be determined by the direction of the triangular pits.[5] Now in the specimen examined, although the acute angle of most of the pits on any given prismatic face would, as a rule, point in the same direction, yet there were fairly numerous examples whose orientation was just the opposite. Again, it was frequently noted that opposite faces in the crystal were acted upon by the corrosive in quite a different manner. One side for instance gave a predominance of the normal triangular pits, with a few of the beaked variety, while the other was characterized by the presence of only a few ordinary pits, and those of a much greater size, the rest being mainly of the beaked type. There was also no apparent connection between the number and arrangement of the pits on opposite sides. On one side, the pits might be very abundant and uniformly distributed, while those on the other would be restricted to one or two small groups. The colemanite experiments of the previous section go a long way towards explaining this apparent anomaly which has been frequently commented upon.

The occurrence of pits of different types on the same crystal face has been noted by many investigators, and suggests several interesting problems, some of which will be referred to later when dealing with the pits obtained by the corrosion of diopside. In the case under consideration at least, it would appear that the various forms are not to be looked upon as differing in kind, but merely in their stage of development.

---

3. ALKALINE CORROSION OF SPODUMENE.

The production of pits upon spodumene by alkaline corrosion is not so readily achieved as by the use of hydrofluoric acid. The corrosive

[5] Jahrb. Min. u. Geol., 1889, 1: 252.

acts with very much greater rapidity, and the specimen frequently becomes covered by a layer of an insoluble silicate which cannot be removed. Several corrosives were used, first a fused mixture of sodium and potassium carbonates, which proved to be altogether too vigorous, then a solution of sodium carbonate at 100° C., which after a very long exposure resulted in a few small and doubtful pits. Finally sodium hydrate was tried, and after an exposure of two minutes over a bunsen flame, pits were obtained of moderate distinctness. When the operation had been interrupted at one minute no pits were found, and after seven minutes' exposure the specimen had been almost dissolved away.

The pits produced differ distinctly from those obtained by acid corrosion. The alkaline pit on the cleavage prism is typically asymmetric and bounded by five sides (Plate XXVI, fig. 18). It has five figure-faces of unequal size and different shape. The angles in some of them were as follows:

ABC	123° 48′
BAC	56° 18′
BCD	90° 0′

It is interesting to note, however, that here as in the case of the prevously described acid pits, the values of the angles were found to vary quite considerably, in one case the angle *B C D* was seen to be 108° 18′.

The tendency observed in the case of acid etching, for the replacement of corners by additional figure-faces, was quite noticeable here also, for pits were seen which had six sides (Plate XXVI, fig. 19). On account of the difficulty in obtaining pits at all, it was not found possible to observe the stages in their growth, but judging from analogy to the results obtained from acid pits on spodumene, as well as to those to be described, obtained from diopside, it would appear that these extra faces were added as the pits attained greater maturity. This process appeared to be more pronounced in alkaline etching, with a resulting tendency to a more complex outline.

A similar example of the occurrence of a larger number of faces in alkaline than in acid pits was found in some etched material kindly placed at my disposal by Professor Walker. Among other preparations of the micas, there were some of phlogopite etched by hydrofluoric acid and fused caustic potash respectively. In the former, most of the pits were of a simple triangular outline while in the latter they were mainly six-sided with the appearance of the face of the hexoctahedron.

On one of the etched faces of spodumene, each one of the pits was provided with a funnel-shaped beak somewhat similar to that obtained

under special circumstances in acid etching. Here, as in the previous experiments, the numbers of the pits on the opposite sides of a crystal were not the same.

In comparing these pits with those described for acid corrosion, no clear relationship was observable. These are typically quadrilateral and those triangular, but there is one shallow, five-sided form illustrated which could apparently have been derived from a triangular form by that replacement which this paper shows to be so characteristic of the growth of etch figures (Plate XXVI, fig. 20).

---

5. ACID CORROSION OF DIOPSIDE.

The excellence of the material procurable made it possible to carry out the corrosion experiments with greater thoroughness in the case of diopside than with spodumene. The faces of the prismatic zone of the former were readily obtained in brilliant condition, and the base and clinopinacoid which are invariably rough and unsuited for crystallographic investigation were artificially cut and polished on one specimen. It was thus possible to prepare a more complete series of the pits of diopside than had yet been published so far as the writer has been able to discover. It was found that not only did the pinacoids give better pits than the prisms, which were the only faces available in the spodumenes, but that the various stages in their development were more clearly defined.

(*a*) *Pits on the prisms.*

A crystal of transparent diopside from De Kalb, N.Y., was exposed to the corrosive action of a mixture of powdered fluorite and sulphuric acid heated over a low bunsen flame for two minutes. On the prisms small pits of a very primitive form were developed (Plate XXVI, fig. 21). They were mere shallow depressions bounded by two sides, one straight and the other curved. One angle was slightly more obtuse than the other, and at this point was situated the deepest part of the pit. In some cases which appeared to be rather more mature, the figure was a steadily deepening groove, one end of which had become a dark, indistinctly bordered hollow.

On continued exposure to the corrosive an interesting modification of the primitive pit was observed. Gradually the borders of the indistinct deep portion took on a definite appearance, until after four minutes there had been developed a quadrilateral pit, bounded by four unequal, triangular figure-faces (Plate XXVI, fig. 22), lying at the end of the shallow depression which represented the primitive pit. As the corrosion con-

tinued, the quadrilateral pit became less clearly defined and finally assumed the form of a shallow depression, in some cases suggesting the more primitive first stage.

Under similar conditions pits of the same type were produced upon the prism faces of other examples not only from the same locality, but also from Zillerthal. In one case, however, while the pits on one side were like those already described, the adjacent prism exhibited pits of a new form. They were of an unusually deep, almost square shape, composed of four triangular figure-faces meeting at an eccentric point.

Experiments of a similar nature had already been made by Greim.[6] In his description reference is made to two types of pit, enclosed, one by three, the other by four, triangular figure-faces. It would seem probable from the preceding experiments, that the two types of Greim are merely pits in two of the stages of that development which is characterized by a successive interpolation of additional figure-faces, as has been brought to light by the method of intermittent etching.

(*b*) *Pits on the clinopinacoid.*

Pelikan[7] experimenting with Nordmark diopsides etched by hydrofluoric acid, produced pits on the clinopinacoid which he described as of two kinds as follows:

(1) Shallow, of rhomboidal outline, the longer pair of sides being parallel with the prism edge, the other pair inclined in the direction of the edge between 010 and 001. Frequently the sharp angles are truncated by a pair of small faces making the pit six-sided.

It will be noted that such a pit would represent the grade of symmetry to be expected on the clinopinacoid of a monoclinic crystal, a face possessed of a binary axis of symmetry. His second type, which did not indicate a symmetry of so high a grade, was described as:

(2) Apparently deeper than (1), usually of somewhat rhomboidal outline, but with the upper edge parallel to the edge between the basal and clinopinacoids.

This is a pit without an axis of symmetry.

These two forms sometimes occurred in correlated position such as might be expected upon the face of a crystal twinned parallel to the orthopinacoid, but as they were not found in vertical rows, Pelikan concluded that this position was not the result of twinning but of a difference in the molecular structure of the crystal. This peculiarity would seem to be inherent in the diopside molecule, for he found these two types in all diopsides examined, and in augites of a chemical com-

[6] op. cit.

[7] Min. u. petr. Mitth., 16: 1. 1896.

position approximating that of diopside, while in true augites the pits were quite normal. This would indicate a grade of symmetry lower than that usually conceded to diopside.

In a critical examination of these results Baumhauer[8] quoted his own previous investigations of Ala diopsides etched by a hot mixture of fluorite and sulphuric acid. In these experiments he had produced pits of the following four types:

(1) Microscopical unevennesses on the unetched faces;

(2) Long, rounded pits, frequently united to form furrows, approximately normal to the edge between the orthopinacoid and clinopinacoid;

(3) Rhomboidal figures, inclined obliquely towards each edge;

(4) Deeper, six-sided forms apparently the result of a greater development of (*c*).

All of these would indicate the presence of a binary axis, the condition of monoclinic holohedrism.

He next examined one of Pelikan's etched crystals on which he found only two definite types of pits:

(1) Deep, dark, holohedral monoclinic pits whose longest side is rotated slightly to the left of the edge between the clinopinacoid and the prism;

(2) Rhomboidal, symmetrical, shallow pits.

His examination of the specimen led him to believe that the other forms described by Pelikan were either very immature pits which if allowed to develop under more corrosion would become symmetrical, or were the result of the fusion of the two general types. In this way he discounted the conclusions of Pelikan as to the symmetry of diopside.

The investigations of Greim which had been published nearly ten years earlier, did not altogether agree with those of these crystallographers. On the clinopinacoid of his crystal from Alexander, N.C., etched by dilute hydrofluoric acid, he had found two types of pits, one bounded by four figure-faces, two parallel trapeziums and two triangles. The other was enclosed by five figure-faces, two pairs of parallel trapeziums and a rhombus. The latter was parallel to the clinopinacoid and its sides were parallel to the upper edge of the figure and thus it formed the bottom of the pit.

This very great divergence between the results of careful experimenters, working with crystals of the same kind, under conditions practically identical, seems to be due to their comparison of pits of different ages. In none of these cases was anything said as to the length of time the corrosion had continued, and by noting the progress of the

[8] op. cit.

action from time to time, as described in the previous section we arrive at the conclusion that age is an essential factor in determining the form of the pit. This became more evident by the following experiments which were made with a view to the determination of the changes which take place during the growth of the pits on the clinopinacoid.

One of the first points to be noted in the experiments to this end is the striking difference between the rates of corrosion on the various faces. The crystal first used, when corroded sufficiently to give clear pits upon the prism, showed an orthopinacoid almost entirely removed, being covered with a closely lying series of long parallel grooves. A similarly striking difference between the rates of corrosion on different crystals was also observed, for, when a crystal of spodumene and one of diopside were heated together in a mixture of fluorite and sulphuric acid over a low bunsen flame for thirty minutes, on the cleavage plane of the former there were well-defined pits while each face of the latter had been etched into hills.

After a sixteen-minute exposure to the action of fluorite and sulphuric acid over a bunsen flame good pits were obtained upon the clinopinacoid. Many of them had a regular rhomboidal form, being enclosed by four triangular figure-faces (Plate XXVI, fig. 24). In some cases however the parallelism of the sides was not perfect, with a result that the symmetry of the pit was of a lower grade than was to be expected on the clinopinacoid of a monoclinic crystal (Plate XXVI, fig. 25). A few even showed the replacement of one of the angles by a fifth face (Plate XXVI, fig. 26).

On a specimen from Zillerthal etched for 33½ minutes by dilute hydrofluoric acid at 100°, some interesting pits were obtained whose orientation indicated the occurrence of repeated twinning. The position of the several individuals of the twin was shown by pits lying side by side in reversed position (Plate XXVI, fig. 27). Between these were pits which were bilaterally symmetrical showing the position of a plane of symmetry. These evidently lay over the edge of the twinning face. Apparently the point of origin of the pit was on this edge, resulting in a kind of pseudosymmetry.

In the experiments here described, pits were obtained which correspond with all those mentioned in the papers to which reference has been made. Most of them are of Pelikan's first type which is about the same as the third of Baumhauer, and the first of Greim. A number were like the second of Pelikan in which the two shorter sides are not parallel. Several of the experiments resulted in pits in which the absence of parallelism was characteristic of the long faces and in some cases neither pair was parallel. The additional pair of figure-faces mentioned by Pelikan was frequently observed, but did not seem always to charac-

terize the asymmetric pit, but in several cases one of the corners had been truncated, resulting in five-sided pits. In one case, a pit similar to the second type of Greim was observed (Plate XXVI, fig. 28). It is also important to note, in view of Baumhauer's explanation of Pelikan's supposedly asymmetric pit, as being the result of twinning, that in the case above mentioned, where the twinning was apparent, the result was not to lower the grade of symmetry of the pit, but actually to raise it.

(*c*) *Pits on the orthopinacoid.*

It has already been pointed out that the orthopinacoid is attacked with much greater rapidity by acid corrosion than is the prism or the clinopinacoid. An exposure of three quarters of a minute to a heated mixture of fluorite and sulphuric acid resulted in the entire solution of the face. Another specimen exposed for a quarter of a minute only, had its orthopinacoid etched into a series of long, parallel grooves, which completely covered the face. Hydrofluoric acid at 100° was next used and a specimen exposed for one quarter of a minute still showed an over-etched orthopinacoid. So, for subsequent experiments it was diluted with an equal amount of water and was found satisfactory.

After an exposure under these conditions, of six and one-half minutes, the first clear pits were obtained. They were enclosed by six sides, the longest pair parallel with the vertical axis of the crystal, the other two pairs closing the ends of the pit, one of which was considerably more acute than the other. This represented a figure enclosed by twelve faces as shown in Plate XXVI, fig. 29.

It differs from the pit obtained by Pelikan on this face. He describes it[9] as a long deltoid, the sharp end of which points towards the base, the obtuse towards the orthodome. Similarly Hintze[10] speaks of the pit as a deltoid with rounded sides, the acute end directed towards the negative, the obtuse towards the positive pyramid. However it is similar to those illustrated by Daly[11] as obtained by etching diopside from Ala with hydrofluoric acid.

In order to obtain if possible a more definite knowledge of the faces which enclose the pits, the Goldschmidt reflection goniometer was used. This is the method already followed by the designer of the instrument in the investigations referred to above. The crystal was set up with the face whose pits were to be examined normal to the axis of the instrument, and the reflections from the pit faces read in the usual way. In view of the clearness of the pits which had been obtained, it was natural

---

[9] loc. cit.

[10] "Mineralogie", 2: 1020.

[11] Proc. Amer. Acad. Arts and Sci., 34: 430. 1889, pl. IV, 15.

to expect that these would be found to be enclosed by ordinary crystal faces, and that reflections from them would be clear and distinct. In this case it would be expected that the reflections would be thirteen in number, a central one representing the unetched crystal face; two on each side in a direction normal to the vertical axis of the crystal, representing the long faces and four on each side of a line connecting these, forming roughly, if joined, two crossing lines, representing the smaller faces.

Instead of this, the reflections took the form of a bright band, brightest in the centre, from which point it steadily became fainter, until at some distance at each side there was a break, followed by a hazy spot at the end. There also extended from the centre two fainter lines above and two below in a slanting direction. This figure would represent the reflections from a boat-shaped pit whose sides and bottom are alike curved. Subsequent investigation however tended to show that this curvature was only apparent and that the effect was due to the fact that the figure faces are numerous, small and differing but slightly in their inclination to the axes.

An additional exposure of the same crystal, bringing the total up to $9\frac{1}{2}$ minutes, under the same conditions, gave pits which were more distinct and considerably larger. When set up on the goniometer as before and examined, it was seen that while the reflection was, as in the previous experiment, in the form of hazy bands, the central one had become noticeably shorter, and all through it were scattered more or less distinct spots of light, which would indicate that for the first time some of the figure faces were large enough or flat enough to yield definite reflections. However they were rather numerous and close together, and consequently could not all of them represent possible crystal faces.

Further exposures gave results of steadily increasing clearness. After the total had been $13\frac{1}{2}$ minutes several of the reflections were the best so far observed. This improvement continued on additional application of the corrosive, until the total time was $23\frac{1}{2}$ minutes, after which there was no increase in the distinctness. Corrosion was discontinued in the case of this crystal after $33\frac{1}{2}$ minutes, but other crystals were etched under the same conditions for a very much longer time. A white diopside from Zillerthal in fifteen minutes, gave small and numerous pits on the orthopinacoid. After further action for fifteen minutes, the pits were sufficiently well developed to give clear reflections, but after a total of forty-five the point of greatest perfection had been passed and the larger, shallow pits were no longer definite enough to be read on the goniometer. Another specimen, a green diopside from

De Kalb, N.Y., reached its greatest clearness in about fifty minutes. These experiments indicate that a maximum of perfection, in which the figure-faces approach to the condition of possible crystal faces in their evenness and position, is attained only after etching has been continued for a considerable time. Further exposure results in gradually decreasing clearness, until the pits have quite lost their original character.

It is interesting to note in passing that in these experiments, as in others in this research, one or two of the pits attained a size many times greater than that of the rest on the same face, persisting even after others had flattened out of all resemblance to their original form. This fact is of significance in developing the theory of the origin of etch-figures as will be seen by the discussion in the second part of this paper.

(*d*) *Pits on the orthodome.*

The faces around the ends of the vertical axis of diopside are almost invariably extremely rough and corroded and quite unsuited for crystallographic examination. In order to overcome this difficulty some crystals were obtained which had the forms (101) and (001) artificially cut and polished upon them. Before being etched they were examined and the artificial faces were found to be correctly cut.

After an exposure of 20 minutes to very dilute hydrofluoric acid, quite definite but minute pits were obtained on the domes. In general form they were somewhat lozenge-shaped. They were each bounded by four figure-faces, two pairs of triangles, one of which was considerably longer than the other. In some cases, a fifth face, small and four sided, formed the bottom (Plate XXVI, fig. 30). It will be noted that this arrangement results in a figure, one of whose ends is deeper than the other. At this stage, the pits were too small to yield any definite reflections of any kind.

On further exposure to the same corrosive the pits gradually increased in size and number and to a certain degree changed in outline. A few were observed which were enclosed by two curved figure-faces. This stage of their development is shown in Plate XXVI, fig. 31.

After thirty minutes' exposure it was found that the pits were still too shallow to admit of measurements, and so a stronger corrosive, commercial hydrofluoric acid diluted with an equal volume of water, was used. This, after an exposure of 20 minutes at 100° gave pits which, while they retained their original outlines, were much larger and deeper. While the perfecting of the faces took place apparently in the same way as in the case of the pits on other faces, the action was not continued long enough to give any clear reflections.

In his experiments with the amphiboles, Daly[12] obtained well defined and uniform figures on the orthodome. They were usually of a regular triangular outline enclosed by three triangular faces. Occasionally however they were five-sided, the result of interpolation of pyramidal faces at the basal angles of the original pit.

(*e*) *Pits on the base.*

The conditions under which corrosion takes place on the basal pinacoid are quite similar to those under which it acts on the domes, and the resulting pits as will be seen from the drawing (Plate XXVI, fig. 32) are very similar, the only difference being that they are somewhat shorter. This shortening is suggestive when we compare the pits on the three principal faces in the ortho-diagonal zone, in which, beginning with the long, almost furrow-shaped figures on the pinacoid, the pits become shorter as we approach the base, where the length is at its minimum.

After an exposure of 20 minutes to a 50% solution of commercial hydrofluoric acid at 100°, conditions under which the figures were developed upon the domes, corrosion had so far progressed that the reflection showed, as in a previous case, a nebulous band in which were a few more or less distinct spots. Further corrosion did not increase the distinctness of the reflections, on the contrary they appeared to become more and more hazy.

---

6. ALKALINE CORROSION OF DIOPSIDE.

In order to obtain pits by alkaline etching, specimens were exposed to the action of fused sodium hydrate, but unlike spodumene, diopside became rapidly over etched and covered by an opaque layer which no amount of washing or boiling with acids would remove. A solution of the same alkali proved ineffectual, but after an exposure of 15 seconds to fused calcium chloride, although the faces of the crystal frequently became clouded, minute but fairly clear and characteristic pits were produced upon the prisms. They were bounded by three sides, one short and straight, the others long and curved and approximately of the same length (Plate XXVI, fig. 33). They were enclosed by three triangular figure-faces, one of which had all three sides straight, while each of the others had one curved side, and were frequently arranged in vertical rows with their short sides lying parallel to a cleavage trace. The only indications of etching upon the pinacoids at this stage were slight roughenings.

---

[12] op. cit., page 413.

A thirty second exposure gave pits of somewhat similar form but with the two curved faces replaced by two short straight ones (Plate XXVI, fig. 34). This suggests that in alkaline etching the same series of events takes place as that which we have seen in the case of acid etching, namely the replacement of curved lines by several shorter straight ones. However, it was difficult to obtain clear pits and in consequence there was not sufficient data upon which to generalize. Extended corrosion, while it seemed to make the pits upon the prisms clearer, did not enable one to obtain any upon the pinacoids. After 40 seconds' exposure, there were no clearly defined pits upon the orthopinacoids, while the clinopinacoid had merely minute, ill-defined spots of roughening.

PART II—THEORETICAL.

1. INTRODUCTORY.

In the first part of this paper there is described a series of experiments with three monoclinic minerals, together with a statement of the observed phenomena. It now remains to combine these results so as to see their bearing upon the general problem of the origin and growth of etch-figures, and as we do so the processes involved begin to take upon themselves a somewhat new significance.

The new generalizations to be deduced from the data now at our disposal may be stated briefly as follows. In the first place the point of origin and the distribution of the pits depend upon the molecular structure of the crystal and not upon any external and adventitious cause. In the second place in its development a pit passes through a regular series of stages comprising growth, maturity and decay. In the third place, there is a relationship between the faces of the pits developed on the various faces of a crystal, and in the fourth place the beaks are shown to be of three kinds, and suggestions to account for their occurrence have been offered.

---

2. THE POINT OF ORIGIN.

As has been pointed out in the experimental part of this paper, one of the striking and unexpected features of etch reactions is that the pits are not distributed evenly over the crystal. The question why one part of the etched face should be free from corrosion, while adjacent parts are closely covered with pits, is one which has attracted the attention of many investigators, and in consequence many explanations have been offered. It is evident that in order to provide an adequate theory

for the general distribution of pits it will be necessary to arrive at a knowledge of the conditions which cause the selection of one point for the location of a pit in preference to another.

Before formulating any new theory it is necessary to review briefly those already suggested and to point out in each case wherein it has failed to satisfy the test of experimental verification. It has been supposed that the presence of extraneous particles such as dust upon the surface would provide points of attack for the corrosive. The experiments in which dusty crystals were exposed without corresponding results, and also the fact that the irregularity is as striking on fresh cleavage faces, show that this idea is quite untenable. But it is possible that there may be fracturings or scratches on the surface in which the corrosive could find a lodgement, unhampered by currents, and so a start might be made. Direct experimental disproof has already been offered in the account of the colemanite experiments, and Daly[13] has shown that such surface fracturings cannot be the universal cause, for in the case of an alum crystal growing in a saturated solution of the salt, a slight dilution of the liquid results in the immediate formation of pits. Under these conditions the crystal faces must have been perfectly unbroken. His conclusion is that the arrangement is "structurally accidental". The possible connection between pits and inclusions which the experiments with colemanite seemed to indicate, was on further consideration seen to be one of a common cause and not of cause and effect. There remains now, in addition to Goldschmidt's theory as outlined in the opening pages of this paper, another, suggested by von Ebner[14], which supposes that the pit originates at the point where particles of the corrosive of greater concentration than the average come in contact with the crystal. Both of these theories are put to the test when action takes place in boiling solution and in a shaken test-tube, and also when the corrosive is applied in the form of a jet. Under such conditions there can be neither eddies nor differences of concentration in the solution.

Since all of these theories fail when put to experimental test, one must look for a clue leading to a new explanation of this unexpected state of affairs. We must bear in mind however, that whatever the conditions may be that allow a selective attack by the corrosive, they must be common to adjacent sides of each cleavage plane, since on these the arrangement of the pits is the same. A suggestive fact in this connection is the growth of pits in overlapping parallelism in more

---

[13] op. cit., page 389.

[14] Sitzber. d. Akad. d. Wissensch. zu Wien, 89: 368. 1884.

or less straight lines. Pits occurring in this linear arrangement were described by Baumhauer[15], who called them "Aetzgraben". These lines are usually irregular, but examples have been frequently observed in which definite crystallographic directions are thus marked by rows of pits. For instance, Böhmer described pits on quartz crystals of concentric growth, which were found to have a corresponding concentric arrangement parallel to the combination edge between $+R$ and $-R$.[16] An even more suggestive example was that previously referred to in the case of diopside, in which the pits were found along the edge of a twinning plane.

It is evident that these lines of selective pitting are also lines of weak cohesion, and we must remember that those faces which present the maximum cohesion, such as cleavage planes, are corroded much more slowly than those of a lower degree. It has also been noted[17] that when a crystal has been fused, the resulting amorphous substance has a lower specific gravity, indicating that the molecules are farther apart, and in consequence the cohesion must be less. Such material has less resistance to the attack of the solvent than had the original crystal. In other words, the stronger the cohesion the greater the resistance to corrosion.

It seems evident therefore that wherever cohesion is less than the average for any crystal face, there is in consequence a point where the corrosive can begin its action. In certain particular cases, such as along the edges of cleavage and twinning planes, the connection between the location of pits and points of weak cohesion is clearly seen, and in others, while not quite so evident at first sight, this relationship is demonstrable, for there can be nothing else in common which could account for the similarity of the arrangement on adjacent sides of cleavage plates. We are now in a position to deduce the law that the point of origin of every pit is at a centre of weak attachments between adjacent crystal molecules. Since, in the process of solution, fresh surfaces are constantly being formed, each of which has its own crop of pits, we conclude that all through the mass of the crystal there are scattered these points of potential pit origin.

It is interesting to note, however, that some individual pits have the capacity of attaining a much greater size than the rest. At first the pits are practically of the same dimensions, but as time goes on, here and there some will be found to be noticeably large. In the ex-

---

[15] "Resultate", page 6.

[16] N. Jahrb. f. Min., Beil. Bd., 7: 540. 1891.

[17] Walker, "Crystallography", N.Y., 1914, page 44.

periments with colemanite it was noted that some of the pits grew vertically downward into the mass of the crystal. In the diopside experiments pits were observed on the orthopinacoid which developed to great size and perfection.

These differences cannot depend upon the corrosive, as they are formed under various conditions. They cannot be accidental in view of what we have already seen as to the causes of the first pit formation. It seems therefore reasonable to suppose that the centres of weak cohesion are more extensive in some cases than in others.

The theory of the distribution of centres of weak cohesion throughout the crystal gives us an explanation for another peculiarity of etching. Daly has observed[18] the occurrence of what he calls "stepped pits", which are deep forms whose sides have a laminated appearance. He explains these as being due to the edges of parallel cleavage planes being brought to light by the corrosion. Pits of this type, while few in number, have been observed from time to time in the course of this research, the most notable instance being that referred to and illustrated in the experiments with colemanite. If a centre of weak cohesion, and therefore, one of potential pitting, be of sufficient extent to lay bare, before the pit has reached its limit, another such centre, the result will be a pit within a pit, and this process, if carried still further, will result in a large pit of the stepped type. The steps in each case being the remnants of the bottoms of the pits which have been so enlarged.

Our deduction as to the point of origin leads us a step further. Since pits are not distributed evenly over the etched face, it follows that the centres of weak cohesion are similarly irregularly placed. Hence the cohesional attachments of a series of crystal molecules in the face will not be uniform. In consequence, the cohesion of any crystal face, as indicated, for instance by its hardness, is not an elementary quantity, but is the mean of an infinite number of variables.

---

3. THE GROWTH OF THE PIT.

Von Ebner in his paper on the etch-reactions of calcite and dolomite concluded that some figures are instantaneous and. some retarded,[19] but Baumhauer remarks: "Instante und retardirte Aetzfiguren sind Endglieder Reihe von Formen, welche sich durch verschiedene Geschwindigkeit der Entwickelung unterscheiden. Sie sind durch Uebergange mit einander verbunden".[20] In the experiment above described

[18] op. cit., page 396.
[19] op. cit., page 775.
[20] "Resultate", page 4.

in which a current of somewhat concentrated corrosive was directed against a crystal of colemanite, the well-defined pits which were produced apparently instantaneously, differed only in size from those produced slowly by a more dilute solution.

The inference is that by the use of a strong corrosive the pits are produced more rapidly than with a weaker one. Many authorities have gone a step farther by the claim that such pits are also more perfect. Miers summarizes this as follows: "Experiments with hydrochloric acid on cylinders of calcite indicate that with a more concentrated solvent the etched faces are produced more readily and in greater perfection than with a dilute solvent".[21] The results of the foregoing experiments, however, show that approximate perfection in the figure-faces depends, not upon the strength of the solvent, but upon the completeness of the processes involved. With a weak solvent this will take place slowly, but in time the result will be the same.

That there is a development of some kind in the formation of the pit has long been known. It is referred to by Baumhauer,[22] who points out that the pits become more numerous and larger until the surface is practically covered. He also observed that after a time they become rounded, but the stages in this process have not hitherto been definitely laid down. It was also made note of by Daly, who remarks, "As the process of etching continues the pit usually increases in size, often (depending partly on the symmetry of the etched plane) changes in shape of outline. . . . The first stage of development in a pit may be called its 'initial' form. The development ends where the outline begins to be seriously impaired by the solution of the surrounding part of the etched surface. Just preceding this point in the history, the pit may be called 'mature', and the process intervening between the initial and mature stages is that of maturing. Von Ebner's 'instantaneous' and 'retarded' types are connected by transitions, but are not easily to be compared to 'initial' and 'mature' figures since his types refer simply to the length of time required to develop the pits and are not restricted to the use of one solvent".[23]

By the application of the method of interrupted etching, the existence of this development was proved and the various stages were isolated and described. They may be stated as follows:

(1) The first stage in pit development is ultra-microscopic, and consists of the attack of the corrosive upon the weak point in the crystal. From this, the rate of attack depends upon the strength of the corrosive.

[21] "Mineralogy", Lond. 1902, page 115.

[22] op. cit., page 3.

[23] op. cit., page 376.

(2) The second, or immature stage is characterized by a shallow, rounded excavation and outlines which are composed of few and curved lines.

(3) As corrosive action continues, the edges which bound the pit tend to become straighter and there is developed in one part a small but definite pit which grows larger, eventually almost filling the primitive depression, which now appears as a slight shadow. Just as the outlines of the primitive pit are curved, so also the earlier figure-faces appear to be curved, though this, as will be seen in the succeeding section, is due, at least in part, to the occurrence of numerous small faces of almost the same symbols, close to one another. During this process the faces become clearer and plainer, and the interpolation of new figure-faces of different indices and in different zones may take place resulting in pits of a more complex outline.

(4) There is a point of maximum perfection, beyond which continued corrosion results in less distinct faces and a broadening rather than a deepening of the pit.

(5) When the edges of expanding pits overlap, leaving a fresh surface marked by etch hills, renewed corrosion results in the formation of a new crop of pits.

---

4. THE NATURE OF THE FIGURE-FACES.

The comparative regularity of the outlines of etch-figures and the apparent evenness of their planes, naturally suggest the idea that they are bounded by simple faces. This was the view of the earlier investigators, whose results were obtained by means of the microscope. Leydolt,[24] the first to consider the problem, thought it possible to express their relationships by means of simple symbols.

But with the application of more exact methods, there came a growing conviction that figure-faces are not as simple in their crystallographic relationships as was at first believed. An examination by Sohncke of the four-sided pits of common salt,[25] showed the symbols of their faces to be 910 and 10, 10. Still further discrepancies were observed by F. Klocke in alum pits[26] whose figure-faces had the symbols 778, 557, 15 1 15, 30 1 30, etc.

When Goldschmidt made use of his two-circle goniometer in the investigation of the subject, the anomalous nature of the pit faces be-

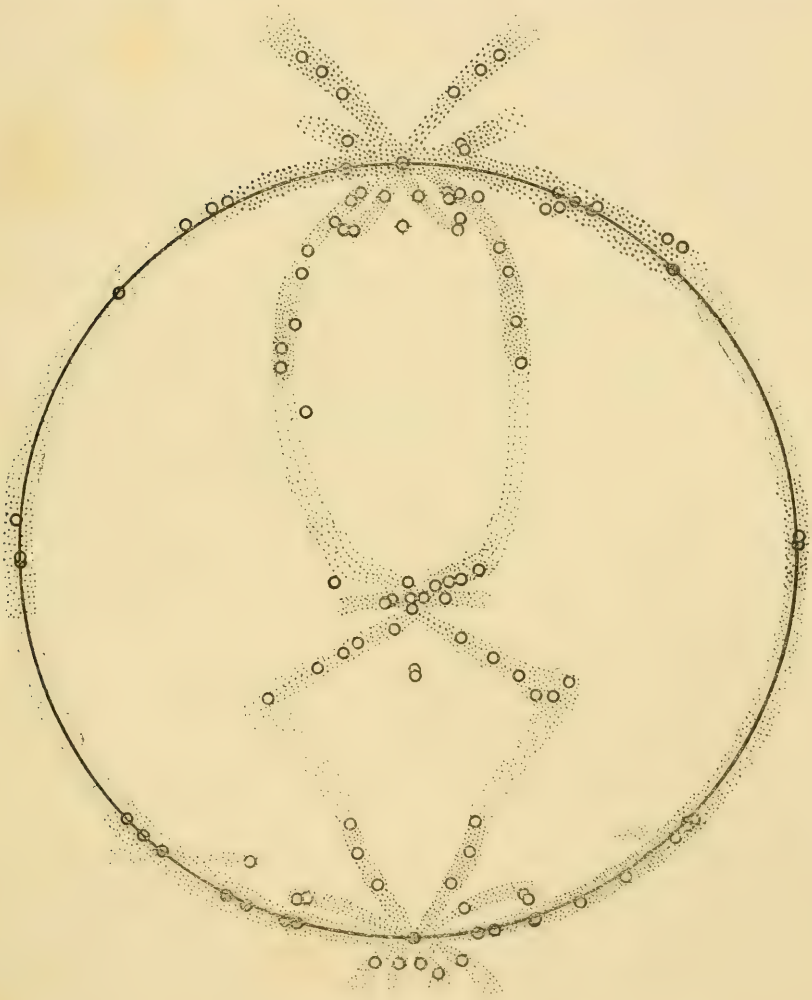
---

[24] Sitzb. der Akad. d. Wissensch. zu Wien, 6 Nov. 1854.

[25] Jahrb. f. Min. 1875, page 941.

[26] Zeitsch. f. Kryst., 2: 126.

came more strikingly evident. The reflections from figure-faces are then seen to differ in a marked manner from those which would be obtained from a series of normal crystal faces. They consist of a number



of light-paths radiating from a common centre. In some cases the rays are long and join in a small central patch of light, and in others it is the centre that is well-defined, and the light-paths are short and indistinct.

In order to make a careful study of these phenomena as exemplified by diopside, a crystal which had been exposed to a 50% solution of

hydrofluoric acid for 15 minutes was mounted on the goniometer and readings were made at intervals along each one of the light-paths Although they were frequently quite dim, they could still be traced in an unbroken series around the crystal in several directions, as is shown in the accompanying stereographic projection. This is characteristic of all the zones.

These observations show very clearly that the faces which form the sides of a pit, and which on microscopic examination resemble crystal faces so closely, are in reality very different. In no case do the parameters bear a simple ratio to one another. In fact, the only type of crystal face with which they seem to have anything in common is the vicinal face.

The length and the continuity of the light-paths would seem to indicate that the reflexions are those from curved faces, and this has been generally assumed. But there are two suggestive observations which militate against this assumption. In the first place, scattered among these indistinct rays there are to be found faint signals like those which might be expected from very small faces. Again it was frequently observed that in order to trace the light-paths it is necessary to move the crystal so that various parts of each face come successively into the field of vision. Further, it was also found that by narrowing the aperture of the telescope's eye piece, the light-paths become shortened and replaced by a series of hazy spots, and sometimes change into clear, though faint crosses.

Evidently then the continuity of the light-paths is not due to the curvature of the figure-faces, but to the fusion of reflexions from numerous pits. This leads to the rather unexpected deduction, which is, however, borne out by numerous observations, that the corresponding figure-faces of pits on the same crystal faces are not identical, though their difference is slight.

Although we must not look upon pits as being enclosed by true crystal faces, it is evident that their bounding planes represent as close an approximation as possible under the circumstances. Goldschmidt has pointed out that in pit formation there are two opposing tendencies, one of which would result in the formation of round excavations if unopposed, and the other in the development of true crystal faces. Thus the net result is these faces which are approximately regular, and hence are of value in the determination of the physical properties of crystals.

Since the symmetry of any pit is an expression of that of the crystal face upon which it is developed, it is natural to expect that there would be some relationship between the pits on various faces of the same

crystal, of such a nature that the form of any one could be predicted. This form is determined to a certain extent by the relative rates of solution in different crystallographic directions. Some pits are long and narrow on account of a marked difference in the rates of solution at right angles to one another, while others are square or even nearly round where there is no difference in the rates. This point has been worked out in some detail by Becke,[27] who, by careful measurements of the diameter of spheres during the process of corrosion, deduced the rule that the velocity of solution varies with the crystal direction. From these velocities it would be possible to construct an ellipsoid of solution corresponding to those illustrating the phenomena of heat and light in the crystal.

Another method of showing the relationship between the pits was suggested by the fact brought to light in the diopside experiments, described in an earlier section of this paper, that the pit on the base resembles that on the orthodome, while the latter resembles to an equal extent, the pit produced upon the orthopinacoid, the three differing mainly in their comparative lengths. In each pair there are some faces in common, and it would be possible to construct a negative crystal from the faces occurring in the pits of the orthodiagonal zone. The result would be substantially the same negative crystal which would be obtained by the union of two pits on opposite clinopinacoids. If it were possible for the corrosive to act within the mass of a crystal, just such a regular cavity would be the result, and, in passing, it might be pointed out that Professor Judd's remarks as to the cause of schillerization, which are quoted on a subsequent page of this paper, would indicate that such an action is not so impossible an event as might at first appear.

In order to discover experimentally whether we have in such a negative crystal a method of correlating the pits of a crystal, a plaster model was made consisting of the following forms: (100), (110), (010), (001), and (011). This is similar in shape to the cast obtained by filling the negative crystal formed by bringing together pits on adjacent clinopinacoids. The portion of the model cut off by any intersecting plane will then represent a cast of a similar portion of the original negative crystal. In order to obtain a cavity corresponding to that of the cut off part of the negative crystal, it is only necessary to imbed this in solidifying plaster in such a way as to keep the hypothetical plane of section in a horizontal position. This was done and the intaglio models so formed are illustrated in the accompanying plate.

---

[27] Min. u. petr. Mitth., N.F., 5: 457.1883.

It must be borne in mind, however, that the figure-faces of the models are those which might be expected to be formed in etching if their development could go on unhindered. That is to say, the pits in the models are enclosed by the minimum number of simple, plane faces, not the indefinite and vicinal faces which we find in actual experience.

The model representing the pit on the orthopinacoid will be observed to be similar to that obtained by etching, with the exception of the faces which close the lower end. These are so inclined as to leave an overhanging edge. This, as has been pointed out by Goldschmidt, in the article already referred to, will provide a point of vigorous attack for the solvent, until the edge is entirely removed. Thus we have the typical pit on the orthopinacoid. It should be remembered in this connection, that in a specimen that has been somewhat overetched one end of each pit is much less clearly defined than the other. The whole pit appears as a groove closed at one end and gradually becoming shallower, until it reaches the surface of the crystal face. The reflection from an orthopinacoid covered with pits of this kind shows a bright light-path corresponding with the prismatic figure-faces, two moderately bright ones corresponding with the faces at the well-defined end, and some faint traces, representing the other end of the pit. This was repeatedly observed in examining crystals with etching developed to this extent. All of which shows that at the point where according to theory we should expect the maximum amount of corrosion, this special rounding off of the pit edges actually takes place.

The model representing the theoretical form of the pit on the orthodome, will be seen by comparing it with figure 31 of Plate XXVI, to bear a striking resemblance to the pit actually obtained by etching. Similarly we find the same relationship between the theoretical and experimental results in the case of the pit on the basal pinacoid, as shown by referring to Plate XXVI, figure 32. In both model and drawing, the faces closing the deeper end of the pit are seen to be steeper than in the case of the dome. Since the pit on the clinopinacoid was taken as the basis from which the negative corrosion crystal was built up, the actual form will necessarily be the same as the theoretical.

The pit on the prism as deduced in this theoretical way, will be seen to be potentially similar to that actually obtained by etching, if we remember, as in the case of that on the orthopinacoid, that the overhanging edge left at the lower part will be the starting point of vigorous solution and quickly removed.

We have, by these experiments, been able to deduce a generalization which may be stated as follows: The relationship between pits developed upon the various faces of the same crystal may be shown if a negative

crystal is formed by bringing together two pits from opposite faces. Then the pit on any face may be obtained by selecting a similar and parallel plane on the opposite side of the centre of symmetry of the crystal, and moving it in towards the centre, in a direction parallel with itself until it cuts off a small portion of the negative crystal. The cavity remaining in the cut off part will be the pit required.

---

5. THE BEAKS.

(*a*) *The nature and classification of beaks.*

The formation of clawed or beaked projections from the bottoms of the pits was an early observed feature of the phenomena of etching. They may be obtained in the majority of crystals under favourable circumstances. Their formation is however not at all what one would expect. It has been shown by Becke,[28] that in the central, open part of the pit, currents produced in the process of etching would remove the solvent as it became saturated with the products of solution and thus expose a fresh supply of unneutralized corrosive. In the corners of the pits this would not go on so rapidly, and action would not be so vigorous. This would tend to make the production of beaks an impossibility, and so it becomes a matter of interest to devise some explanation for their existence.

The foregoing experiments show the existence of three types of beaks, two of which are heretofore undescribed. We have, in the first place, that form which extends from one corner of the pit, and which is apparently superficial, and which may be called the "crack beak" (Plate XXVII, fig. 35). In the second place we have the normal beak extending from the deepest part of the pit, and in the third the tubular beak, which may have no apparent connection with any pit, and which may extend for a considerable distance within the body of the crystal.

(*b*) *The crack beaks.*

The characteristics of the crack beak are described in greater detail in the case of colemanite, but examples were also observed in the etching of diopside. It appears like a crack extending in the direction of the production of the longer side of the pit through one of the acute angles. It is evident that on any crystal face parallel to the vertical axis in any crystallographic system, except the isometric, the direction of the most easy and rapid solution will be indicated by the longest side of the pit, and that inclined toward this and parallel to another side of the pit,

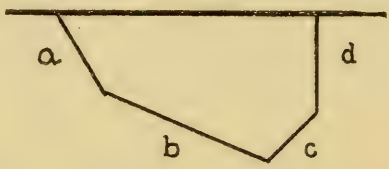
---

[28] Min. u. petr. Mitth., 7: 240. 1885.

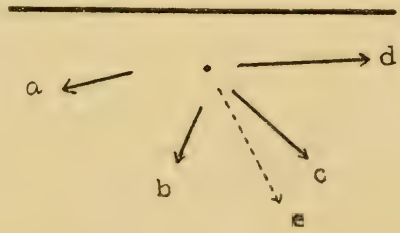
there is a direction of slowest solubility or greatest resistance. The crack beaks are then merely extensions of the longest side of the pit in the line of least resistance.

(*c*) *The normal beaks.*

The processes which result in the formation of normal beaks are, like those leading to beaks of the other types, so obscure that any attempt at discovering them is beset with many difficulties, but some of the facts observed in the foregoing experiments seem to suggest an explanation. The fundamental fact should first be noted that the beaks always spring from the deepest part of the pit. Many times pits were observed which had this deepest part developed in such a way as to warrant the conclusion that beaks were just beginning to grow. In some cases one of the side walls was seen to be steep, vertical or even overhanging. In others, the deepest part, at the base at such a steep side had become enlarged so as to form a knob-like projection. The forces acting upon a particle of the solvent in such a narrow corner, are indicated in the diagram. Of the four figure faces here indicated

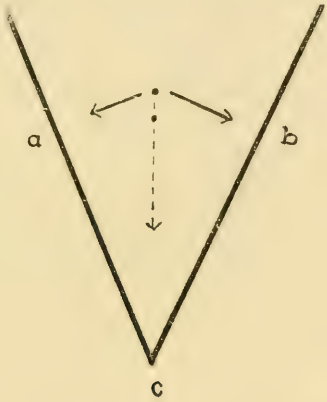


in the diagram, the longest, *b*, is the most slowly attacked and therefore has the least attraction for the particles of the solvent, while the smaller, *a*, *c*, and *d*, are those of most rapid solution and therefore of greatest attraction. In consequence each particle of the solvent is under the influence of forces which draw it toward the faces illustrated, and will move in the resultant direction *e*. The most



rapid solution, then, will take place at the point where the line of motion strikes a face of the pit. The result of such action will naturally be to accentuate the depth of the deepest part.

Any such deep corner will be the starting point of a beak, in the form at first of a somewhat tapering excavation. A particle of the solvent in a position within this, will be attracted by forces in the directions *a* and *b*, and will tend to follow their resultant in the direction *c*, and thus



increase the length of the excavation. The transition from this to a normal beak can readily be conceived.

(*d*) *The tubular beaks.*

The processes which are here described as tubular beaks, and which consist of capillary tunnels running in various directions throughout the crystal, might be supposed to be the result of the enormous development of normal beaks. But this cannot have been their mode of origin, for the action described in the previous section could not take place in such a narrow space. Many of them indeed are apparently not connected with pits. Their growth is probably due to the ease with which corrosion can take place parallel with a cleavage plane, and which is so pronounced that such directions have been called "solution planes".

Several examples were observed in which two pits were joined by a connecting tube which evidently owed its existence to such a cause. If conditions were such that the tubes could develop along these planes the result would be a number of cavities arranged in a definite crystallographic direction. But in the most pronounced cases the tubes were not confined to any plane. Their irregularity must have been due to their deflection from their ordinary course by coming in contact with successive points of weak cohesion.

This phenomenon is of interest in view of modern theories of the origin of schillerization. For many years this has been known to be

due to the presence of numerous inclusions arranged in parallel position. They are usually of a definite crystalline form, often similar to that of the host, but sometimes they are branching or trichitic inclusions of varied outline. Now Judd has pointed out[29] that, while the inclusions have a crystalline form, they are isotropic and the form therefore cannot be their own. "I am led to the conclusion that the substances forming the various enclosures do not consist of any definite chemical compounds assuming the regular crystalline form belonging to mineral species but that they are a mixture of various oxides in a more or less hydrous condition, such as hyalite, opal, gothite and limonite, hence their isotropism, their varieties in colour and their resistance to the action of acids". In other words the inclusions are pseudomorphs.

It was also shown that while all the inclusions had one parallel pair of faces, the rest of their outlines were very frequently irregular, and closer examination revealed the fact that in these cases the inclusion did not completely fill its cavity. In view of this Judd adds: "The suggestion which seems to me to be most in accord with all the facts of the case is that those enclosures are of the nature of negative crystals which are more or less completely filled with the foreign substance, the enclosures assume the outlines of true crystals, though they do not of course exhibit their optical properties".

Goldschmidt has shown in the paper above referred to that if an etched crystal be placed in a saturated solution of the same substance the pits themselves attract the dissolved particles and in consequence immediately become filled. It follows then that such negative crystals cannot have been left in the growth of the host. Judd suggests that they may have been due to the subsequent action of etching, though he does not offer any explanation of its occurrence within the substance of the crystal and not on its surface.

Further, schillerization is to be observed only in deep-seated rocks, and Judd believes that as the silicates are known to be soluble to a certain extent in water at a great heat and under high pressure, it is to this action that we are to look for the cause both of the corrosion resulting in the production of the negative crystals and of their subsequent filling with foreign material. According to the conclusions reached in the paper above quoted, schillerization is due to a process of etching which attacks the interior of the crystal rather than its surface, and to the subsequent filling of the cavities so formed by an isotropic substance derived from the mineral itself.

The only stage in the process left unexplained is the formation of

---

[29] Quart. Jour. Geol. Soc., 41: 384. 1885.

the negative crystals by etching, and the experiments described in the preceding paragraphs appear to give some indications of the conditions under which this would take place in nature. In the laboratory we have a gentle corrosive—dilute hydrofluoric acid at 100°—acting for a considerable time upon a crystal, in nature we have a corrosive perhaps equally mild—water at a high temperature and pressure—acting upon a crystal for a much greater time, and the results are quite comparable. It is true that the channels and negative crystals in the natural examples may be much larger than in the artificial, a result quite in keeping with the fact, which these experiments illustrate, that slow etching tends to make possible the production of larger etch-figures. Furthermore as a link in the chain of evidence, it is interesting to remember that naturally etched crystals are occasionally met with, as, for example, that of spodumene from Alexander, N.C., described by Dana.[30]

---

[30] Zeitsch. für Kryst., 6: 509.

EXPLANATION OF FIGURES.

Fig. 1. Immature pit in shallow depression, Colemanite (010), 1% Acetic Acid, 100°.

Fig. 2. Two adjacent pits connected by a tube, Colemanite (010), 1% Acetic Acid, 100°.

Fig. 3. Immature pit in shallow depression, Colemanite (010), 1% Hydrochloric Acid, 100°.

Fig. 4. Pits in parallel arrangement, Colemanite (010), 2% Hydrochloric Acid, 100°.

Fig. 5. Pit on Colemanite (010), 2% Hydrochloric Acid, 100°, after second exposure.

Fig. 6. Deep pit remaining after a third exposure as above.

Fig. 7. Typical symmetrical pit, Colemanite (010), 100°, third exposure.

Fig. 8. Asymmetric pit, Colemanite (010), 4% Hydrochloric Acid, 100°.

Fig. 9. Beaked pit, Colemanite (010), 6% Hydrochloric Acid, 100°.

Fig. 10. Very immature pit, Spodumene (110), Sulphuric Acid and Fluorite, 15 minutes.

Fig. 11. Second type of pit, less immature, Spodumene, as before.

Fig. 12. Third type of pit, Spodumene (110), as before.

Fig. 13. Beaked pit, Spodumene (110), as before.

Fig. 14. Fifth type of pit showing rudimentary beak, Spodumene (110), as before.

Fig. 15. More mature pit, Spodumene (110), Sulphuric Acid and Fluoric Acid, 30 minutes.

Fig. 16. Deeper form showing a perpendicular and a curved side, Spodumene (110), as before.

Fig. 17. Four-sided pit on Spodumene (110), fused Sodium Hydrate, 2 minutes.

Fig. 18. Five-sided pit on Spodumene (110), as before.

Fig. 19. Six-sided pit on Spodumene (110), as before.

Fig. 20. Shallow five-sided pit on Spodumene (110), as before.

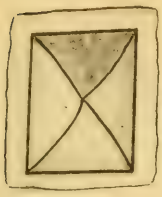
Fig. 21. Primitive pit, a mere shallow depression, Diopside, De Kalb, N.Y. (110), Sulphuric Acid and Fluorite, 2 minutes.

Fig. 22. Pit in second stage, Diopside (110), same corrosive, 4 minutes.

Fig. 23. Unusual asymmetric pit, Diopside, Zillerthal (110), same corrosive, 4 minutes.

Fig. 24. Typical pit, Diopside, Zillerthal (010), same corrosive, 16 minutes.

Fig. 25, 26. Asymmetrical pits, same mineral, same conditions.
Fig. 27. Pits occurring above and on either side of edge of twinning plane, Diopside, Zillerthal (010), same corrosive, 33½ minutes.
Fig. 28. Typical flat-bottomed pit, like Greim's second type, Diopside, Zillerthal (010), same corrosive, 18¾ minutes.
Fig. 29. Typical pit, Diopside, Zillerthal (100), 50% Hydrofluoric Acid, 6½ minutes.
Fig. 30. Pit on Diopside, Zillerthal (101), dilute Hydrofluoric Acid, 100°, 20 minutes.
Fig. 31. Pit on Diopside, Zillerthal (101), dilute Hydrofluoric Acid, 100°, 30 minutes.
Fig. 32. Pit on Diopside, Zillerthal (001), 50% Hydrofluoric Acid, 100°, 20 minutes.
Fig. 33. Pit on Diopside (110), fused Calcium Chloride, 15 seconds.
Fig. 34. Pit on Diopside, Zillerthal, same corrosive, 30 seconds.
Fig. 35. Colemanite etched with 10% Hydrochloric Acid, 100°, showing "crack beak".
Fig. 36. Colemanite, 2% Hydrochloric Acid, 100°, showing the position of pits on adjacent sides of a cleavage plane. The line surrounding indicates the corners of the fragment.
Fig. 37. Plaster model of diopside crystal.
Fig. 38. Model of theoretical pit on the base.
Fig. 39. Model of theoretical pit on orthodome.
Fig. 40. Model of theoretical pit on orthopinacoid.
Fig. 41. Model of theoretical pit on prism.
Fig. 42. Model of theoretical pit on clinopinacoid.

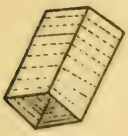

1

2

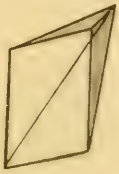
3

4

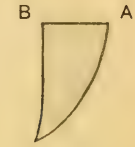
5


6

7

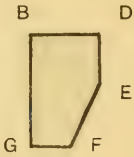

8

9

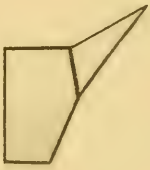


10

11



12


13

14

15

16

17

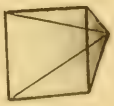
18

19

20

21

22


23

24

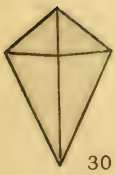
25

26

27

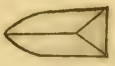
28

29


30

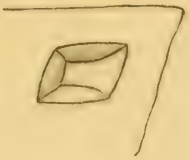
31

32

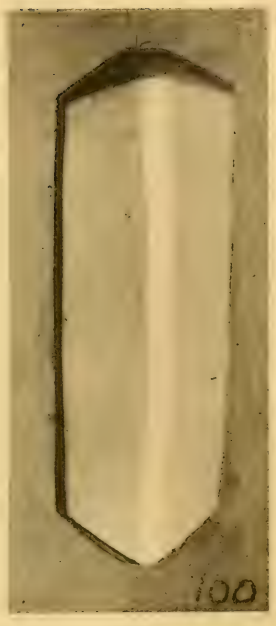

33

34

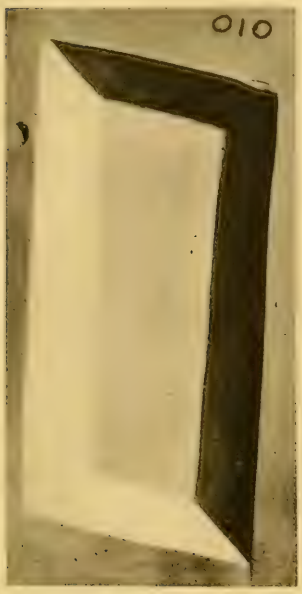
35



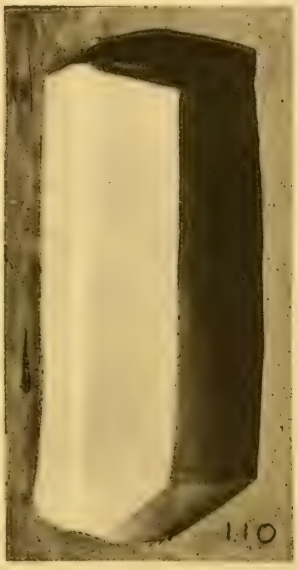
36



40



42



41

39

37

38

THE MINING AND METALLURGICAL TREATMENT OF MOLYBDENUM ORES IN CANADA.

G. C. MACKENZIE.

By Permission of the Director of Mines Branch.

The opening of the great European war found the British Empire lacking in adequate supplies of certain metals that were urgently required for the manufacture of munitions. We had grown so accustomed to securing many of these metals from foreign reduction works, that, rather than spend money in the exploitation of our own natural resources, we depended upon the foreigner to supply our requirements, because it was easier and cheaper to buy what he had to sell than to go to the trouble and expense of developing our own supplies.

This penny-wise, short-sighted policy of the past, with its foolish disregard of future contingencies, has cost the Empire much lost time in the manufacture of munitions, and, thereby, many valuable lives of its brave soldiers. The experience has been costly, but the lack of these materials has at least brought about an awakening that promises the adoption of a wiser policy in the future. Not the least of these deficiencies has been the lack of the steel hardeners, tungsten and molybdenum, and as these metals are important factors in the manufacture of modern ordnance and ammunition, the curtailment of supplies during the first two years of the war was a serious matter.

The story of the production of tungsten is in itself sufficient material for a long article, and cannot be dealt with at the moment, and as the subject of this address is molybdenum, I will confine myself to a description of its occurrence as a mineral and its use as a metal.

The name Molybdena, now applied only to the metal Molybdenum and its compounds, really means lead, and has come to us from the early Greeks who used the term to describe all of the dark metallic sulphides. The resemblance between lead, molybdenite and "black lead" or graphite especially, is best evidenced by lack of discrimination between them and our retention of the ancient confused term black lead and lead pencil. No doubt when better means of determination arose, the easiest one to identify, lead, was eliminated, but the difference, superficially slight, did not permit classification until late in the phlogiston

period. The name molybdenum for many centuries, therefore, pertained to graphite and molybdenite which were considered identical.

It is interesting to note how these two were finally distinguished. By the action of nitric acid upon molybdenite, Scheele, in 1778, three years before his work on tungsten, showed that there were formed sulphuric acid and a white acidic earthy substance which we term molybdic acid to-day. In 1779, Scheele firmly established the difference between the two minerals, theretofore confused, in another treaty on plumbago. In the Phlogiston way, the earth was considered the calx of a metal, and on this theory, in 1790, facts were made known regarding the first preparation of the metal by Hjelm, who, prompted by the current belief that carbon was rich in phlogiston, ignited the acid oxide of Scheele in a graphite crucible with carbon. The resulting gray metal must have contained considerable carbon. That process is commercially used to-day.

Until recent years, the metal was in little demand for industrial purposes, and very little search was made for the ores of molybdenum. At the present time, however, owing to its introduction into metallurgy, in the form of iron molybdenum alloys, there is a considerable demand for such ores. They are produced, however, very irregularly and in small quantities. If a larger and more regular ore supply were assured, there is no doubt that new uses would be found for the metal, its alloys and salts, and the demand for the ores would increase.

PROPERTIES AND USES.

Physical and Chemical Properties of Molybdenum: Pure molybdenum is a white metal, which is malleable, ductile, and soft enough to be filed and polished with ease. However, it is seldom produced in the pure state, and its appearance depends largely upon the method of production. Reduction of the oxides or sulphides of molybdenum with hydrogen yields molybdenum as a grey powder, which, under heat and pressure, may be compacted into a metallic bar that is brittle and even fragile. Molybdenum produced by the Alumino Thermic methods or by reduction in the electric furnace is a compact metal, but that produced in the electric furnace contains carbon, and its physical properties differ from those of carbon-free metal. The melting point of molybdenum is still in question. The United States Bureau of Standards has placed it at about 2,500° C., or 4,500° F. This is about 1,400° C., above the melting point of copper, and 740° C., above that of platinum. Osmium, tantalum and tungsten are the only three metals listed by the Bureau of Standards as having higher melting points. The specific gravity of molybdenum is increased appreciably by drawing or hammer-

ing the metal, as is that of many other metals, such as copper and tungsten. The Research Laboratory of the General Electric Company has determined the specific gravity of ductile molybdenum before drawing as 10.02, whereas, after drawing, it ranges from 10.04 to 10.32. Molybdenum wire has a tensile strength approximately one-half that of hard-drawn steel piano wire or tungsten wire of corresponding size, and this tensile strength increases very appreciably with the fineness of the wire. In other words, the more the metal is worked the stronger it becomes. The electrical resistance of ductile molybdenum is 5.6 microhmes per cubic centimeter of hard-drawn wire, and 4.8 for annealed wire, the resistivity being measured at 25° C.

Metallic molybdenum containing carbon is grey and brittle; it is also very hard and scratches steel and quartz, and even the hardest file will not cut molybdenum alloyed with a certain proportion of carbon The melting point of the grey metal is much lower than that of pure molybdenum, and its specific gravity is also lower, ranging from 8.6 to 8.9, according to the amount of carbon present. Pure molybdenum surrounded with carbon and heated to about 1,500° C., absorbs carbon and becomes hard; conversely, carbon-bearing molybdenum melted with molybdenum-dioxide is refined by the oxidation of the carbon in the metal.

Pure molybdenum undergoes oxidation to an appreciable extent at the ordinary temperature, but it is superficially attacked at a dull red heat, and rapidly at 600° F., molybdenum trioxide subliming. Dilute acids have no effect upon it. Strong nitric acid oxidizes it, so does concentrated sulphuric acid, and at the same time there are formed lower oxides, which are soluble in the acid with the formation of a deep blue colour. The halogens attack it with a formation of more or less volatile, variously coloured halogen and oxy-halogen compounds.

The massive metal, on account of its less surface exposure, is less active toward reagents than the powder molybdenum.

The trioxide is volatile at high temperature.

Uses: Molybdenum is used in the form of oxides, ammonium salt and metal. Several tons a year are used in North America in the form of ammonium molybdate for the determination of phosphorus in iron ores, pig irons and steels, and also in the determination of phosphorus in fertilizers. The salt finds further use in fire-proofing certain fabrics. The metal is used in self-hardening steel; from five to ten per cent. is introduced, and the resulting steel is raised in elastic limit and tensile strength and possesses greater toughness in addition to the former property.

Ferro-Molybdenum is found to be of value as a constituent in the manufacture of large castings, gun barrels, in which it is prized for its resistance to corrosive gas action, armour plate, armour-piercing shells, car steel, and magnets.

Equal parts of molybdenum and chromium introduced into steel are claimed to be more preferable for many of the above uses, especially self-hardening steel. Two to five per cent. of molybdenum and ten per cent. chromium with little or no carbon will make steel acid resisting to a great degree. Nickel steels alloyed with molybdenum are found to possess desirable qualities. The tensile strength of molybdenum wire is given at from 200,000 to 270,000 pounds per square inch, as compared to tungsten with 480,000 to 580,000 pounds per square inch.

Molybdenum wire-wound electric furnaces have special claims made for them. A thermocouple which uses the metal has been described recently. The lower oxides of molybdenum are highly coloured. Their use is recorded in colouring leather, rubber and porcelain. A soluble variety is used as a substitute for indigo.

In some form not disclosed, molybdenum is added as a preservative to certain smokeless powders.

The principal use of molybdenum, however, is in the manufacture of special steels to which, particularly in conjunction with chromium, manganese, nickel, cobalt, tungsten and vanadium, it imparts many desirable properties. These steels are used for a large variety of purposes, such as for crank and shaft forgings, high pressure boiler plate, ordnance, armour-plate, armour-piercing projectiles, permanent magnets, wire, and self-hardening and high speed machine tools. In a general way, molybdenum acts like tungsten in steel, but it is more active, and less is needed to produce a given result. Absolute figures as to the relative effect of the two elements cannot be given, as the effects are not exactly similar. The effective ratio of molybdenum to tungsten seems to be between one to two and one to three.

Metallic molybdenum is used in various electrical contact making and breaking devices, X-ray tubes and voltage rectifiers, and in the form of wire for filament supports in incandescent electrical lamps, for winding electric resistance furnaces, and in dentistry, as a molybdenum tungsten alloy.

CANADIAN MOLYBDENUM PRODUCTS.

The only molybdenum products manufactured at present in Canada are C.P. molybdic acid, C.P. ammonium molybdate, and ferro molybdenum. The International Molybdenum Company manufacture all three of the above at their Orillia, Ontario, works, this Company being

the first Canadian operator to establish the molybdenum business on a commercial basis, therefore being the pioneer of this new industry.

The Tivani Electric Steel Company of Belleville, Ontario, have commenced the manufacture of ferro-molybdenum quite recently, but so far have made no attempt to produce molybdic acid or ammonium molybdate.

The manufacture of metallic molybdenum, ingot, molybdenum wire, molybdenum steels, etc., is not carried out in this country, but it is well within the range of possibility that, providing the mines are able to produce sufficient minerals to meet the demands of the market, all of these various lines of manufacturing will be entered into within the Dominion.

I am unable at this time to give particulars of the manufacture of these molybdenum products, but it may be stated that Canadian ferro-molybdenum, molybdic acid and ammonium molybdate are now being marketed satisfactorily, and that the production of ferro-molybdenum up to the end of 1916 was in the neighbourhood of thirty tons. The value of the molybdic acid and ammonium molybdate manufactured at Orillia during 1916 is stated by the management of the International Company to be $18,867.35.

ECONOMIC MOLYBDENUM MINERALS.

Only two molybdenum minerals—molybdenite and wulfenite—are common enough to form molybdenum ores.

Molybdenite: Molybdenite, the disulphide of molybdenum (MoS_2), contains 59.95% molybdenum, and 40.05% sulphur. It is opaque, lead-grey, and has a metallic lustre and a greasy feel. It is so soft (hardness 1 to 1.5) that it soils the fingers readily, and leaves a bluish-grey trace on paper. On porcelain its streak is slightly greenish. The specific gravity ranges from 4.7 to 4.8. Molybdenite commonly occurs in flakes or scales, resembling those of some micas in the way that they may be split into thin leaves. Finely, granular and massive forms are also common. Molybdenite crystallizes in hexagonal form, with crystals being tabular, or short and slightly tapering prisms.

Molybdenite is often confused with graphite, but may be easily distinguished because graphite is much lighter (specific gravity 2.09 to 2.23). Heating a fragment of the mineral in an open tube will conclusively settle any question as to its identity, for molybdenite gives strong sulphurous fumes, whereas graphite gives none.

Molybdenite, on weathering, commonly forms molybdite, a hydrous ferric molybdate ($Fe_2O_3 - 3MoO_3 - 7\frac{1}{2} H_2O$), which theoretically contains 39.63% molybdenum. In colour, molybdite is a lemon-yellow to pale

yellow, and occurs as an earthy powder, in crustations, fibrous masses, or capillary crystals in radiating groups. For many years molybdite was thought to agree in composition with the artificial molybdic trioxide obtained by oxidizing molybdenite, and most of the present text-books on mineralogy persist in this error, giving its composition as MoO_3. Iron, however, is an essential part of the mineral. Molybdite by its colour often calls attention to deposits of molybdenite which otherwise might be unnoticed.

Tests: Heated in an open tube, molybdenite gives off sulphurous fumes, and a pale yellow crystalline sublimate of molybdenum trioxide (MoO_3) is formed. Before the blow-pipe molybdenite is infusible, but imparts a yellowish-green colour to the flame. On charcoal in the oxidizing flame, pulverized molybdenite gives a strong odour of sulphur dioxide, and the charcoal is coated with crystals of molybdic acid, which appear yellow when hot and white when cold. Near the assay the coating is copper-red, and if the white coating be touched with an intermittent reducing flame it assumes a beautiful azure-blue colour. Molybdenite is decomposed by nitric acid, leaving a white or greyish residue (molybdic oxide).

Occurrences and Accompanying Minerals: Probably three-quarters of the reported occurrences and practically all of the commercial deposits of molybdenite so far discovered are in acid rocks, such as granite, pegmatite, and syenite, the mineral being notably at home in rocks of this type. Outside of the gangue-forming minerals, such as quartz, felspar, mica, garnet, calcite, fluorspar, etc., the minerals with which molybdenite is most frequently associated are molybdite (its alteration product), pyrite, pyrrhotite, chalcopyrite, malachite, chrysocolla. Other accompanying minerals are native copper, cuprite, chalcocite, bornite, tetrahedrite, azurite, galena, sphalerite, arsenopyrite, magnetite, limonite, wolframite, hübnerite, scheelite, cassiterite, and bismuthenite.

Wulfenite: Wulfenite is a molybdate of lead ($PbMo_4$), and theoretically contains 26.15% molybdenum, and 56.42% lead. It is heavy and brittle, sub-transparent and sub-translucent, and has a resinous or adamantine lustre, and generally a wax or orange-yellow colour. It may, however, be green, grey, brown, nearly colourless, or orange to bright red. The streak is white. The hardness is 2.75 to 3 and the specific gravity is 6.7 to 7. Wulfenite crystallizes in the tetragonal system, the crystals commonly being square and tabular and sometimes extremely thin. The mineral generally occurs in well crystallized forms, but also in coarse or fine-grained masses.

Tests: Before the blow-pipe wulfenite decrepitates and fuses below 2. With borax in the oxidizing flame it gives a colourless glass, which in the reducing flame becomes an opaque black or dirty green with black flecks. With salt of phosphorus in the oxidizing flame it gives a yellowish-green glass, which becomes dark green in the reducing flame. Heated with soda on charcoal, the powdered mineral yields metallic lead. On evaporation in hydrochloric acid it decomposes, forming lead chloride and molybdic oxide. Moistening the residue with water and adding metallic zinc gives an intense blue colour, which persists after dilution.

Occurrences and Accompanying Minerals: Deposits of wulfenite are found almost wholly in veins, where it is associated with other lead minerals such as galena, cerussite, pyromorphite, vanadite, anglesite and descloizite. Gold and silver minerals also occur with it, and native gold is sometimes contained directly in the wulfenite crystals.

Up to the present time, however, the mineral molybdenite has constituted the only economic ore of the metal in Canada.

PRICES AND MARKETS.

Molybdenite ores and concentrates are marketed on their content of MoS_2, and are paid for as so much per unit of contained molybdenum sulphide. In Canada and the United States, the short ton of 2,000 pounds and the unit (1% of a ton) twenty pounds, are used, whereas, in Great Britain and Australia, the long ton of 2,240 pounds and the unit of 22.4 pounds always apply.

Under existing abnormal market conditions, brought about by the war, the prices being paid at the present time for molybdenite concentrate are from 100 to 200% greater than pre-war quotations. In 1908, high grade concentrates containing 90 to 95% MoS_2 were sold for $6.50 to $7.60 per unit, and in 1909 the price was as low as $5.65 per unit.

In the Fall of 1915 the Imperial Government fixed a price of 105 shillings per unit (long ton) for molybdenite concentrates containing not less than 85% MoS_2, f.o.b., London and Liverpool, and as the mineral was under embargo which prohibited its export to any country outside of the British Empire, this price naturally became the official standard quotation for all ores and concentrates produced within the Empire. Since that date, however, licenses have been granted for the export of the mineral to France and Russia at the official quotations given above.

The quotation, it should be noted, means 105 shillings per unit, 22.4 pounds of molybdenite (MoS_2), not 85% concentrates as many have imagined. This price corresponds to $1.09 per pound of MoS_2 contained in 85% concentrates, f.o.b., Ottawa, Ontario, at which point

the Canadian production is purchased for the Allied Governments by the Imperial Munitions Board.

Canadian molybdenum purchased by the Imperial Munitions Board at Ottawa in the form of molybdenite concentrate, is, at the moment, being converted to ferro-molybdenum in Canada before being exported to Europe, and as it is possible to manufacture the ferro-alloy from concentrates containing less than 85% MoS_2, the following sliding scale of payment has been adopted by the Board:

(*a*) For concentrates containing not less than 85% molybdenite, $1.09 per pound of contained MoS_2.

(*b*) For concentrates containing not less than 80% molybdenite, $1.05 per pound of contained MoS_2.

(*c*) For concentrates containing not less than 75% molybdenite, $1.02 per pound of contained MoS_2.

(*d*) For concentrates containing not less than 70% molybdenite, $1.00 per pound of contained MoS_2.

It is difficult to forecast with any accuracy the future conditions of the industry, but it is reasonable to assume that with increased production and a more normal market, the present prices will decline. It is possible that with the end of the war consumption may keep pace with production as the metal has a multitude of useful applications in the peaceful arts; however that may be, producers would do well to assume that a drop in price is inevitable with the end of the war and to prepare themselves accordingly.

CANADIAN PRODUCTION.

The mining and metallurgical treatment of Canadian molybdenum ores has up to 1916 played a very small part in the world's production. This has been due to various factors, chief of which have been the limited demand for the mineral and at unattractive prices, together with the fact that no Canadian mine had until 1916 been developed to the point of a steady producer.

In 1911, the Mines Branch of the Department of Mines published a monograph entitled "Report on the Molybdenum Ores of Canada" by Dr. T. L. Walker, of Toronto University; and while this report contained considerable detailed information regarding the various localities throughout the country in which ores of molybdenum occurred, it was at that time impossible to foretell with any degree of accuracy, the probabilities of Canadian production, or to describe commercial methods of preparing the ore for the market.

In 1915, the Mines Branch, in response to a circular issued by the Colonial Institute of Great Britain, commenced a detailed examination

of the molybdenum ores of Canada; and as the Department at this later date were fully equipped to experiment on the problem of concentration, the investigation consisted for the most part in looking for a solution of the problems involved in preparing the ore for market.

The Department secured large samples in carload lots which were shipped to the Testing Laboratories of the Mines Branch in Ottawa. After much patient research work with the more common specific gravity types of ore concentrating machinery, the conclusion was reached that concentration methods based upon specific gravity would not yield commercial results and therefore a solution of the problem would have to be looked for in other directions.

After coming to the conclusion that the older processes of concentrating minerals would not apply, the possibilities of separation by flotation were carefully looked into and for a time it was considered that the modern Oil Flotation Process would probably be adopted. However, during a laborious and detailed examination of this method, there were encountered certain difficulties in the application of the Oil Process which indicated the desirability of continuing the investigation for an easier method of working. This method was eventually found in what has been called the Water Film Flotation Process, and although commercial results were not immediately attained the process lent itself readily to adjustment, and as the factors governing the separation of molybdenite from its gauge by this method were more completely understood, a type of apparatus was gradually evolved which is at the present time in successful operation at the Ore Testing Laboratories of the Department.

The principle upon which this method is based is the surface tension of water, advantage being taken of the fact that molybdenite resists wetting, while its associated minerals are more or less easily wetted and submerged.

The method of separating molybdenite from other minerals by means of projecting the ore upon a sheet of flowing water has been known for many years, but the first commercial application of the process on a large scale was made by Henry E. Wood, of Denver, Colorado, who patented the Wood Water Film Flotation Machine in the United States and Canada.

About the time the officials of the Department had satisfied themselves that water film flotation was the most desirable process for the separation of the majority of Canadian ores, attention was directed to the Wood type of apparatus, and after consultation with Mr. Wood it was decided to install one of his machines at the Testing Laboratories in Ottawa. Subsequently, certain weaknesses in the Wood machine

developed in the treatment of some of our Canadian ores and the Department in endeavouring to correct these weaknesses and to improve upon the general adaptability of the machine, have evolved a type of apparatus which has been found to work very satisfactorily under almost all conditions.

While the Department were experimenting for a solution of the separation problem, the search for molybdenite deposits of economic value continued throughout the country. Old deposits were re-opened and developed with more vigour than heretofore and many new discoveries were made, but it was not until the spring of 1916 that the industry as a whole was strengthened by the development of the "Moss Mine" of the Canadian Wood Molybdenite Company, near Quyon, Pontiac County, Province of Quebec. The occurrence of a mineral resembling graphite had been known in this locality for many years, but it was not until January, 1916, that the identity of this mineral was definitely established as molybdenite.

The Canadian miner of molybdenum ores while encouraged by the reported prices for the mineral during 1915 had no definite guarantee that his product when ready for market would be accepted by the Imperial authorities; and as the great majority of these miners were men of small means it was difficult for them to raise the necessary capital for development without such assurances or contracts from the Imperial authorities. In June of 1916, the Imperial Munitions Board at Ottawa announced that they were in a position to purchase a considerable tonnage of molybdenite concentrates in Canada to be delivered before June 30th, 1917. At this time the Laboratories of the Department of Mines at Ottawa possessed not only the best concentration equipment, but were also in possession of a staff that had considerable experience with the problem of concentration. It was, therefore, natural that the Imperial Munitions Board should turn to the Department of Mines for assistance in the securing of a part of the tonnage of concentrates above mentioned, and an arrangement was entered into between the Imperial Munitions Board and the Mines Branch of the Department of Mines whereby the latter became the millers and assayers for the Board in all matters pertaining to the supply of metallic ores and minerals.

The Moss Mine of the Canadian Wood Molybdenite Company having at that time developed sufficiently to make shipments, an agreement was drawn up with that Company whereby they were to supply the Mines Branch of the Department of Mines with 100 tons of molybdenite ore weekly, the concentrates produced therefrom being purchased by the Imperial Munitions Board. At the same time, the Mines Branch

advertised their willingness to treat small parcels of ore originating from other localities and while no other mines of the magnitude of the "Moss" have been encountered to date, the Department received during the year about 217 tons from other sources.

The method first adopted for the purchase and settlement of these ores was as follows:

The miner was required to deliver his ore carriage paid to the Testing Laboratories of the Department, and after the ore had been milled he was to receive the proceeds from the sale of his molybdenite at approximately $1.09 per pound of MoS_2 f.o.b., Ottawa, less the cost of concentration—between $5.00 and $6.00 a ton. No definite recovery was guaranteed. In December, 1916, it was found possible to standardize milling operations and to fix a definite cost per ton for the ore treated together with definite schedule of guaranteed recovery of molybdenite. This schedule is as follows:

Terms of Purchase of Molybdenite Ores, Department of Mines, Ottawa.

(1) On assay returns from samples dried at 212° F.

(2) For dry ores—moisture to be deducted.

(3) The cost of concentration to be $5.65 per net ton.

(4) The value of Molybdenite (MoS_2) to be $1.00 per pound, Ottawa.

(5) Payment to be calculated as follows per ton of 2,000 lbs. dry ore delivered on siding at Mines Branch Testing Laboratories, Ottawa:

Molybdenite Ores containing:

(*a*)	Between	0.5%	and 1%	for 70%	of the	total	Molybdenite	(MoS_2)	Content.
(*b*)	"	1.1%	and 1.5%	for 78%	"	"	"	"	"
(*c*)	"	1.51%	and 2.0%	for 84%	"	"	"	"	"
(*d*)	"	2.1%	and 2.5%	for 87%	"	"	"	"	"
(*e*)	"	2.51%	and 3.0%	for 90%	"	"	"	"	"
(*f*)	"	3%	and ..	for 92%	"	"	"	"	"

(6) Net returns to the miner will be the value of the ore calculated as indicated above less $5.65 per net ton concentration charges.

The Departmental Plant has operated since June, 1916, and up to the first of February, 1917, has treated 2,397 tons of crude ore and picked flake with the production of 34.85 tons of pure molybdenite in the form of a concentrate averaging 80% MoS_2. The ore treated contained 1.84% molybdenite and the actual molybdenite shipped has been 79.09% of the total amount received. The total recovery would be slightly over 80% as no account has been taken in this calculation of the several tons of middling product in process of milling.

THE INTERNATIONAL MOLYBDENUM COMPANY OF ORILLIA.

The International Molybdenum Company of Orillia, Ontario, with concentrating mill at Renfrew and smelter at Orillia, have been in opera-

tion since 1915. During the past year this company have milled approximately 2,419 tons of molybdenite ores of which approximately 26 tons were derived from the United States. According to figures supplied by the management of the company, the average content of the ore milled was 1.23% MoS_2 with a production of approximately 60,000 pounds of molybdenite. The recovery has been estimated to be 80% of the total amount of molybdenite received.

This company are under contract with the Imperial Munitions Board for 50 tons of ferro-molybdenum of which they have already delivered in the neighbourhood of 30 tons. The ferro-molybdenum must comply with the following specification:

Molybdenum	70% minimum.
Carbon	4% maximum.
Sulphur	0.4% maximum.

The alloy must be arsenic and copper-free.

The International Company manufacture their ferro at Orillia from commercial molybdic acid produced in their chemical plant. The concentrate required as raw material is supplied partly from their own concentrator at Renfrew and partly by the Imperial Munitions Board at Ottawa. The ferro alloy produced by the International Company has been found entirely satisfactory as regards analyses, and is sold to the Imperial Munitions Board at a price of $3.25 per ton of contained molybdenum, delivered f.o.b., Montreal. Therefore, a ton of 2,000 pounds of ferro-molybdenum containing exactly 70% Mo., is worth $4,550. The ferro-molybdenum is shipped to the Testing Laboratories of the Department of Mines at Ottawa where it is crushed, sampled, assayed and repacked for shipment to Europe by the Mines Branch officials; and it may be of interest to note that the weighing and analytical work of the Mines Branch has to date proved so satisfactory that the weights and assays determined by the Department are final and binding on both parties to the contract. The International Company control two molybdenite mines, the O'Brien, situated on Mount St. Patrick, Renfrew County, Ontario, and the "Molly" mine at Salmo, Sheep Creek, B.C. These two properties, however, are insufficiently developed to meet the capacity of the concentrating mill at Renfrew and the Company have treated a considerable tonnage of customs ore during the year.

The method of concentration adopted by the International Molybdenum Company is water film flotation, but the machine developed by the Company staff is somewhat differently constructed than either the Wood Machine or the apparatus developed by the Department of Mines. The principles involved are, however, exactly similar, and

while the International Molybdenum Company have not produced concentrate of as high grade as the Department of Mines, the recovery of molybdenite is said to be equally as good and the product sufficiently high in molybdenite to meet the requirements of their refinery at Orillia.

THE CANADIAN WOOD MOLYBDENITE COMPANY.

The Canadian Wood Molybdenite Company, Ottawa, with mines at Quyon, Que., and mills at Quyon and Hull, Que., are unquestionably the foremost producers of molybdenite ore and concentrates in North America. Since the mine started operations in March, 1916, this Company has mined approximately 5,000 tons of ore, and from assay returns supplied by the Canadian Wood Company together with figures arrived at by the Department of Mines, it is estimated that the ore averaged 1.7% MoS_2 with a total content of 85 tons of pure molybdenite. Assuming that 80% of the total amount has been recovered at least 68 tons of pure molybdenite have been recovered from this property during 1916.

Early in the fall of 1916, the Canadian Wood Company commenced the installation of a water film flotation mill at their property at Quyon. This mill with a capacity of 50 tons of crude daily was not completed until some time in December owing to difficulties encountered in securing machinery and supplies. The Company have also made an arrangement with the Canada Cement Company whereby the latter crush and pulverize the ore as it is delivered to them at Hull, Que., and transport it to a 100 ton water film concentrator mill erected by the Canadian Wood Company on the Cement Company's grounds.

The Canadian Wood Molybdenite Company have a contract at the present time with the Imperial Munitions Board at Ottawa for the total output from their mills at Quyon and Hull in addition to the 100 tons of ore which they have contracted to deliver weekly to the Department of Mines.

SMALLER PRODUCERS.

In addition to the foregoing may be mentioned the molybdenite mine of Wm. J. Spain, situated in the Township of Griffith, in the County of Renfrew, and also the property of the Renfrew Molybdenum Mines, Limited, Mount St. Patrick, County of Renfrew, together with a prospect being developed by A. M. Chisholm in the Township of Sheffield, County of Addington, all in the Province of Ontario.

The Spain mine was active for about the half of 1916, and shipped to the Department of Mines, in Ottawa, 3½ tons of molybdenite in the form of flake and ore. During the early spring a 50 ton mill was erected on the property, but has not yet been operated to capacity, as the mine

has been insufficiently developed to supply the necessary tonnage. The mill consists, essentially, of a rock crusher, rolls, picking belts and screens, and has produced several tons of medium grade concentrate which it is understood are held at the property for future concentration.

The Chisholm mine opened up as a rather promising prospect and was so considered until the property of the Canadian Wood Company at Quyon completely overshadowed it in the matter of quick production. The Chisholm mine is being operated by open cut and the management have installed a small roll and screen cobbing plant of sufficient capacity to treat 15 tons of ore in 10 hours. This cobbing plant was installed with a view of cobbing the run of mine which is in the neighbourhood of 1% up to a shipping product of 15% molybdenite or better; the intention being to send the cobbed mill product to the Testing Laboratories at Ottawa, where it will be milled to a commercial grade.

The Renfrew Molybdenum Mines, Limited, are working a property on Mount St. Patrick about 11 miles from Ashdod Station on the Kingston and Pembroke railway. This mine is probably in a more advanced stage of development than any other molybdenite mine in Ontario. Some years ago the mine was opened up by an adit tunnel driven to intersect a hillside vein. The tunnel encountered the vein about 80 feet on the incline below the surface and proved the ore to exist at that depth and to contain about 1% molybdenite. In 1916, active work was commenced and we are informed that a shaft has been sunk on the vein to a depth of 75 feet at which point the vein has been found to persist in both width and molybdenite content. During the fall of 1916, a single unit Elmore Vacuum Flotation plant was installed at the property and milling operations were commenced some time in December. The management state that with the Elmore plant they are treating from 30 to 40 tons daily and producing therefore 500 to 1,000 pounds of 80% concentrate.

So far, the entire production of the Renfrew Molybdenum Mines, Limited, has been exported to France where this Company have a contract to fill with one of the Metallurgical Departments of the French Government.

BRITISH COLUMBIA.

While we have records of several promising Molybdenite prospects in British Columbia this Province has not—up to the present time—produced any merchantable concentrate, the western miner having contented himself with making shipments of crude ore.

In the fall of 1916 the Canadian Munition Resources Commission engaged J. C. Gwillim, Professor of Mining Engineering, Queen's

University, to investigate and report upon the possibilities of securing supplies of certain minerals in British Columbia; and while Professor Gwillim investigated or actually inspected some 45 different occurrences of molybdenite his report indicates that there are but a half-dozen localities from which a tonnage of Molybdenite ore may be expected within the near future.

The following notes have been compiled very largely from Professor Gwillim's report together with such other information as is readily accessible through Government reports, etc.

The *Molly Mine*, situated on Lost Creek, about 15 miles from Salmo, in Kootenay, has shipped at various times during 1914 and 1915 approximately 50 tons of high grade ore to the Henry E. Wood Testing Plant at Denver, Colorado. In 1916 this property, under the management of the International Company of Orillia, Ont., has produced about 74½ tons of cobbed ore which has been shipped to the concentrator of the International Molybdenum Company at Renfrew, Ontario. It is understood that the Molly mine may be looked upon as a small producer of high grade ore for some little time to come.

The Molybdenum Mining and Reduction Company of Vancouver, who control a molybdenite mine on the Alice Arm of Observatory Inlet, 14 miles above Granby Bay, have expended a considerable amount of capital in the development of their property and may eventually become one of the more important producers in British Columbia. The molybdenite in the ore from this mine is in the so-called amorphous condition, that is to say, the crystallization is so fine that it cannot be distinguished by the naked eye and this ore, therefore, presents some peculiar problems in concentration. The ore is essentially a mixture of Molybdenite and quartz, very little Pyrite or other accessory sulphide being present and mica is almost entirely absent. The problem of concentration, there fore, is more particularly that of grinding the ore to a fineness at which the maximum amount of molybdenite is freed from the quartz and the subsequent separation of the finely divided molybdenite from the gangue. Such finely ground material is difficult to concentrate with any degree of efficiency by water film flotation methods and the probabilities are that one of the Oil Flotation processes will have to be adopted. The management have so far been unable to produce a merchantable concentrate on a commercial scale and the property is for the present inactive pending arrangements which will permit the installation of a suitable milling plant.

A shipment of 350 tons of ore from this property, said to be the average run-of-mine, was made to the concentrator of the International Molybdenum Co. of Orillia, Ontario, late in the fall of 1916. It is

understood that the ore contained on the average 1.25% of molybdenite, but unfortunately owing to the extremely fine crystallization of the molybdenite the International Company have been unable up to the present time to attempt the milling of this shipment.

A third property which may develop into a producer is a prospect called the *Index* mine situated between Cayuse and Cottonwood Creeks, Lillooet Mining Division. This property was worked for a short time during the fall of 1916 by Mr. Newton W. Emmens, of Vancouver, who made a shipment of 8 tons of high grade ore to the concentrator of the International Molybdenum Co. at Renfrew, Ontario.

Other properties mentioned by Professor Gwillim as being worthy of some attention are as follows:

Stave Lake—7 miles north of Stave Lake on Stump River, owned by Moses Bouchier, Mission, B.C.

Pitt River—10 miles from the north end of Pitt Lake, owned by A. Hewitt, Vancouver.

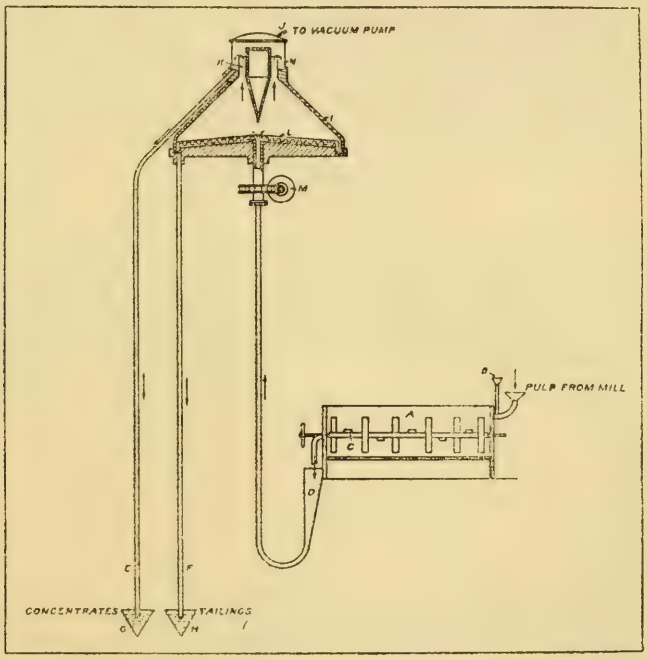
Grande Prairie—20 miles south of Ducks, owned by C. A. Mackay, Adelphi, Post Office.

THE ELMORE VACUUM FLOTATION PROCESS.

The apparatus is illustrated diagrammatically in Figure 1, and its operation may be briefly described as follows: The crushed ore from the pulverizing mill flows continuously into the mixer "*A*", into which are introduced small quantities of oil (in the separation of molybdenite the oil used is preferably kerosene) and if required, of acid also, at point "*B*". The pulp with its addition of oil is beaten to an emulsion in the mixer by the rotation of the agitator "*C*". The emulsion then flows from "*A*" into the funnel "*D*". The concentrate and tailing discharge pipes "*E*" and "*F*" are both sealed with water in the tanks "*G*" and "*H*", respectively. The feed pipe from "*D*" enters the centre of the vacuum or separating chamber "*I*". By regulating the flow of pulp down tailing pipe "*F*" so as to be less the up flow through feed-pipe "*D*", a small quantity of liquid is induced to overflow the annular lip "*K*" and to carry with it the floating concentrate down the concentrate pipe "*E*" into tank "*G*". The series of rakes "*L*" are rotated by means of the gear drive at "*M*", and these rake blades are set at sufficient angle to cause the gangue in the pulp to move from the centre of the chamber "*I*" toward its periphery and to discharge continuously down the tailing pipe "*F*" into tank "*H*". The feed pipe "*D*" is usually 25 to 30 feet long with the concentrate and tailing pipes "*E*" and "*F*" made a few feet longer so that the pulp is syphoned from the mixer

"*A*" through the machine into tanks "*G*" and "*H*". Provided that a continuous flow of pulp is supplied, a continuous and entirely automatic discharge of tailing and concentrate is secured. The annular space "*K*" is provided with a thick glass window through which the operation of the machine may be observed.

The apparatus is supplied in single units that are said to have a capacity of from 25 to 50 tons of crude per 24 hours, depending upon the nature of the ore.



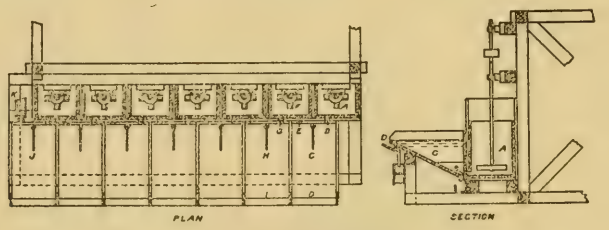
Section of Elmore Vacuum Concentrator

MINERALS SEPARATOR PROCESS—HOOVER VALVELESS APPARATUS.

This machine is illustrated in Figure 2 which shows a plan and section of the apparatus. The ore with its additions of oil and acid is fed into "*A*" where it is agitated for a time and emerges at the opening "*B*" into box "*C*". Any sulphide that floats in box "*C*" is removed at its lip "*D*". The bulk of the pulp is then drawn through port "*E*" into the mixer "*F*", whence, after further agitation, it is discharged from port "*G*" into box "*H*" where more flotary sulphide is removed at lip "*I*" and so on continuously throughout the series, alternately agitating and delivering sulphide froth until the last frothing-box "*J*", where

the tailing now depleted of valuable sulphide is allowed to escape through valve "*K*". The agitators in the mixing compartments are driven at a peripheral speed of 1,500 linear feet per minute.

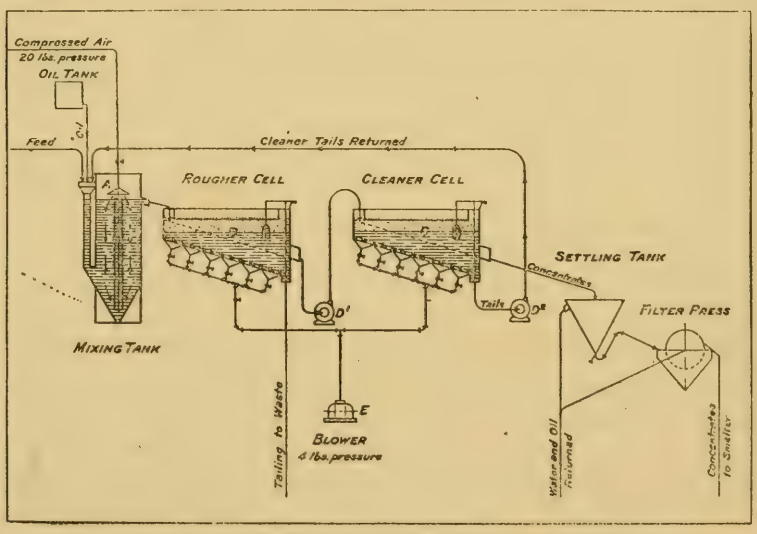
The machine may be constructed with six, eight, or more agitators and may have a capacity anywhere from 50 to 100 tons of ore per 24 hours.



HOOVER VALVELESS APPARATUS
MINERALS SEPARATION PROCESS

CALLOW PNEUMATIC FLOTATION PROCESS.

This process of flotation is illustrated in Figure 3 and may be easily followed by the following description: The preparation of the pulp by violent agitation is not essential for this process; the ore from the pulver-



Callow Pneumatic Flotation Process

izing machine passes into the mixing tank "*A*" along with the necessary oil and acid, while compressed air is blown through the pulp in the

mixer in order to keep the solid matter in suspension. From the mixer, the pulp flows to the rougher cell "*B*" into which air is blown and atomized through a porous cloth material on the bottom of the cell. Tailings are discharged from "*B*" through a bottom port controlled by a float valve, while the valuable sulphide, a rough concentrate, proceeds to a cleaner cell "*C*" where it undergoes a cleaning retreatment. The cleaner cell discharges tailing still containing valuable mineral to the mixer tank "*A*" and a finished concentrate which is delivered to a filler press. A Standard unit is said to treat from 35 to 75 tons per 24 hours depending upon the nature of the ore.

MOLYBDENITE PRODUCTION.

AUSTRALIA—NORWAY—CANADA.

Ton—2,000 lbs. From 1900 to 1916. There are no authentic records for the United States.

YEAR	AUSTRALIA		NORWAY		CANADA	
	TONS	VALUE	TONS	VALUE	TONS	VALUE
1900	C 11	$2.730		$		$
1901	C 26	7.830	C 4.40	1.890		
1902	C 53	34.407	C 22.04	16.200		
1903	C 40	28.124	C 34.16	21.600	M 3.40	1.275
1904	C 46.25	24.304	C 33.06	17.550		
1905			C 50.69	16.470		
1906	C 145?	82.898	C 28.63	14.310		
1907	C 72	58.429	C 33.06	12.960		
1908	C 98	49.893	C 38.57	13.500		
1909	C 121	60.935	C 33.06	12.150		
1910	C 153	86.222				
1911	C 121	77.229	C 2.20	740		
1912	C 159	102.200	C 12.12	3.510		
1913	C 145	125.564	C 3.86	3.240		
1914	M 139?	241.586?	M 59.51	119.732?		
1915	M 129?	281.220?	M 82.65	180.177	M 12.75	27.795
1916	M 132?	287.760	M 100.00?	218.000?	M 83.69	183.434
Totals	1590.25	1,551.331	538.01	652.029	99.84	212.504 B

Explanation.—C = Concentrate, M = Molybdenite (MoS_2), ? = doubtful accuracy.

Summary	*Tons*	%
Australia produced	1590.25	71.3
Norway produced	538.01	24.1
Canada produced	99.84	4.5
	2228.10	99.9

STATEMENT.

MOLYBDENITE ORES TREATED AND CONCENTRATE PRODUCED DURING 1916 AND TO FEBRUARY 1ST, 1917.

Ore Testing Laboratories, Mines Branch, Department of Mines, Ottawa.

CRUDE ORE AND FLAKE, RECEIVED				PRODUCT MADE			
SHIPPED BY	WEIGHT LBS.	%MoS_2	CONTENT LBS. MoS_2	CONCENTRATE MADE LBS.	%MoS_2	MoS_2 RECOVERED LBS.	% of RECOVERY.
Canadian Wood Co. Co. of Pontiac, Que.	4,360,749	1.74	76,303.2034				
Horcroft, T. Co. of Victoria, Ont.	72,664	1.38	1,004.910				
Offer, William C. South Porcupine, Ont.	915	15.31	140.09				
O'Brien, M. J. Co. of Renfrew, Ont.	50,324	1.45	732.15				
Padwell, George Co. of Haliburton, Ont.	111,280	1.40	1,560.2368	87,179.51 lbs. 43.58 Tons	79.95%	69,696.7625 lbs. 34.85 Tons	79.09%
Renfrew Molybdenum Co. Co. of Renfrew, Ont.	109,558	1.29	1,410.40				
Ross, C. G. Co. of Renfrew, Ont.	19,784	0.45	88.6				
Spain, W. J. Co. of Renfrew, Ont.	69,482	9.89	6,868.72				
Urqhart, W. J. Toronto, Ont.	35	35.25	12.34				
Total	4,794,791 lbs. 2,397.4 Tons	1.84%	88,120.6502 lbs. 43.58 Tons				

MBL WHOI Library - Serials
5 WHSE 02814